MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. JUNE 12, 1891. No. 8

Lieut.-General J. F. TENNANT, R.E., C.I.E., F.R.S., President, in the Chair.

Richard Edward Synge Cooper, Hillmorton Paddox, Rugby;
Hugh Frank Newall, M.A., Trinity College, Cambridge;
Samuel H. Ridge, B.A., F.R.G.S., 275 Victoria Parade East, Melbourne, Victoria;

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended:—

Lord Edward Spencer Churchill, Castlemead, Windsor (proposed by the Earl of Rosse).

Seventy-eight presents were announced as having been received since the last meeting, including amongst others:—

W. Harkness, The Solar Parallax and its Related Constants, including the Figure and Density of the Earth, presented by the U. S. Naval Observatory; Harvard College Observatory, Variable Stars of Long Period, presented by the Observatory; O. A. L. Pihl, The Stellar Cluster χ *Persei* Micrometrically Surveyed, presented by the author; Observations of the Total Eclipse of the Sun, 1889, January 1, made by the Washington Observatory party, presented by the Observatory; H. Raper, The Practice of Navigation and Nautical Astronomy, 19th edition, presented by the publishers; Cincinnati Observatory, Charts and Micrometrical Measures of Nebulæ, presented by the Observatory; Siddhanta Siromani (Hindu Astronomy), presented by Col. Waterhouse; Pulkowa Observatory, Supplément aux Observations: Catalog von 5634 Sternen, von H. Romberg, presented

by the Observatory; J. Kleiber, On the Determination of the Orbits of Meteor-Streams [in Russian], with an abstract in English, presented by the author.

Researches on the Mean Density of the Earth. By Prof. A. Cornu.

On the invitation of the President, M. A. Cornu gave the following brief account of the experiments he has been making for some years past with M. J. B. Baille in order to measure the constant of Newtonian attraction, or of the mean density of the earth :—

L'appareil, analogue à celui de Cavendish, Baily et Reich, est fondé sur l'emploi de la balance de torsion; il est formé d'un levier horizontal (tube d'aluminium) suspendu à un long fil de torsion (4 mètres); il porte à ses extrémités les deux boules attirées (en cuivre, bismuth, fer ou platine) et en son milieu un miroir vertical réfléchissant les traits d'une échelle millimétrique placée à 5 mètres; deux masses attirantes (de mercure) produisent un couple de torsion dont on peut inverser le sens, ce qui double l'effet. Les déplacements de l'échelle, observés avec une lunette, mesurent les déplacements angulaires du levier.

Les principaux perfectionnements apportés à l'appareil primitif sont les suivants :

1°. *Le levier est reduit* à $0^{m}{\cdot}50$ c.-à-d. *au quart de la longueur* adoptée par Cavendish, Baily et Reich; l'appareil étant quatre fois moins long peut être renfermé dans un espace plus étroit et plus uniforme de température. La diminution du levier a encore un autre avantage en vertu du théorème suivant: Toutes choses égales d'ailleurs (masses attirantes, masses attirées, distance des masses attirantes aux masses attirées, durée d'oscillation du levier), la déviation par l'attraction newtonienne, indépendante des masses suspendues, est en raison inverse de la longueur du levier.

2°. *Les masses attirantes* ont pu alors être *réduites* à 10 *kilogrammes* sans cesser de donner des déviations mesurables à $\frac{1}{500}$ près, ce qui facilite beaucoup la manœuvre de l'inversion (les masses attirantes de Cavendish dépassaient 140 livres). De plus pour éviter les chocs inévitables dans le déplacement des masses, on a remplacé le plomb par du mercure. A l'aide d'une aspiration convenable, on fait passer ce liquide dans des sphères creuses en fonte sans la moindre trépidation.

3°. *La loi complète des oscillations du levier est enregistrée* sur un cylindre enfumé. A cet effet, l'observateur donne un *tap* sur une clef électrique au passage des divisions de l'échelle sous le réticule de la lunette : divers artifices très simples établissent la concordance des divisions observées et des signaux enregistrés. On peut ainsi vérifier que les oscillations du levier satisfont à la loi

$$x = Ae^{-\alpha t} \sin 2\pi \frac{t - to}{T}$$

qui est l'intégrale de l'équation différentielle du mouvement de rotation d'un système solide soumis à *deux espèces de forces seulement*: 1° les unes proportionnelles au déplacement (torsion, variation de distance des masses en présence etc.), dont la résultante constitue la force équilibrant l'attraction et qu'il importe de déterminer avec précision; 2°, les autres, proportionnelles à la vitesse (amortissement par l'air, par le frottement intérieur du fil de torsion etc.) qui interviennent comme influence perturbatrice.*

4°. *Le fil de torsion doit être recuit* en le maintenant suivant une direction sensiblement rectiligne avant de l'ajuster au levier de la balance. On élimine ainsi toutes les anomalies qui se présentent dans les balances de torsion (instabilité du zéro, déplacement continu avec le temps etc.) et qui proviennent vraisemblablement de l'état moléculaire forcé imprimé au fil par l'écrouissage et l'enroulement antérieur sur une bobine.

5°. *Le levier de la balance de torsion doit être en communication métallique avec la boîte conductrice qui l'enveloppe et avec le sol.* On évite ainsi les perturbations qui proviennent des variations de potentiel électrostatique de l'air et des supports, du haut en bas de l'appareil.

6°. *La boîte protectrice du levier de la balance de torsion doit être en métal bon conducteur et d'épaisseur assez grande.* En effet les variations accidentelles de température d'un point à l'autre de la boîte produisent des courants d'air qui se traduisent par des efforts hydrodynamiques d'un ordre de grandeur considérable et affectant une allure très régulière. Ainsi, une bougie allumée placée à quelques centimètres du levier protégé par une boîte de zinc mince attire énergiquement la boule la plus voisine: on a pu ainsi répéter toutes les expériences du radiomètre de M. Crookes avec cette différence, que l'action apparente d'un corps chaud est ici une attraction au lieu d'une répulsion. La substitution à la boîte en zinc mince d'une boîte en cuivre rouge, épaisse de 3 millimètres, a fait disparaître ces phénomènes singuliers: la grande conductibilité calorifique du cuivre pur empêche la localisation de la chaleur transmise et par suite fournit l'équilibre continuel de température autour du levier.

Telles sont les principales précautions nécessaires pour parvenir à la régularité complète des observations: il ne reste plus maintenant, pour arriver au chiffre définitif, qu'à effectuer un petit nombre d'expériences accessoires destinées à estimer l'approximation assignable aux mesures.

* Ce mode d'enregistrement est assez précis pour qu'on ait pu mettre en évidence, mesurer et éliminer l'influence d'un troisième genre de force, introduit à dessein (action proportionnelle au carré du déplacement.)

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1890; *and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.* By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The present paper contains the observations of the right ascensions and north polar distances of the Moon, made at the Radcliffe Observatory during the year 1890. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions :—

(1) That the mean times, found in the usual way from the sidereal times at mean noon, given in the *Nautical Almanac*, were *not* changed in 1864 by the adoption of a different unit of time.

(2) That these mean times *were* changed in 1864 by the adoption of a different unit of time to fix the positions of the clock stars relatively to the Sun, in accordance with the views which I have explained in papers communicated to the Society.

In the Appendix to the *Monthly Notices*, vol. l., will be found the results of a comparison between the Greenwich Lunar Observations, 1847–1861, and Hansen's Tables, of greater accuracy than had before been available for use; and these results have been utilised to form the mean results given in Table III.

An examination of the residual errors shows that the motion of the Moon was closely represented by Hansen's Tables during the period 1847–1863, although periodical errors of no inconsiderable amount, due either to defects of theory or to imperfections in the practical methods of comparing the theoretical and observational results, are shown to exist.

The mean annual error in longitude of Hansen's Tables from 1847 to 1863 is, however, only $-1''\cdot85$, and no law of regular increase is apparent; but Table III. shows that when the time, t, is found as at present, the mean annual error has increased since 1863 at an average rate of $0''\cdot72$ per annum, and that the error now amounts to $+18''$. The mean annual error of Hansen's Tables from 1864 to 1890 taken out with the *corrected* argument is $-1''\cdot44$, which differs but very slightly from the mean error between 1847 and 1863.

For facilities for an accurate comparison between Hansen's Lunar Tables and Observations, I am again indebted to the places published in the *Connaissance des Temps.*

TABLE I.

Radcliffe Observations of the Moon, 1890.

R.A.'s and N.P.D.'s of the Centre of the Moon, 1890; *compared with Hansen's Tabular Places*, **Uncorrected** *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1648.

Day, 1890.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in N.P.D.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in R.A.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Jan. 8	38·60	R.	II.	9 34 16·09	16·95	+0·86	−1·30	−0·44	S.	71 29 8·77	13·35	+4·58	−5·00	−0·42
29	38·68	F. B.	I.	4 2 52·33	53·42	+1·09	−1·32	−0·23	S.	71 57 20·43	18·55	−1·88	+5·30	+3·42
Feb. 3	38·70	F. B.	I.	8 25 54·85	55·89	+1·04	−1·36	−0·32	N.	68 1 33·21	34·95	+1·74	−3·09	−1·35
5	38·71	R.	II.	10 7 45·32	46·25	+0·93	−1·29	−0·36	S.	73 54 44·26	49·51	+5·25	−5·94	−0·69
9	38·72	R.	II.	13 19 31·07	31·92	+0·85	−1·26	−0·41	S.	93 7 45·60	53·89	+8·29	−8·28	+0·01
12	38·74	R.	II.	15 56 23·70	24·74	+1·04	−1·49	−0·45	S.	107 43 30·80	34·75	+3·95	−6·21	−2·26
27	38·80	W.	I.	5 27 22·82	23·82	+1·00	−1·38	−0·38	S.	67 28 23·70	20·99	−2·71	+2·78	+0·07
Mar. 3	38·81	W.	I.	8 59 17·54	18·63	+1·09	−1·34	−0·25	N.	69 26 29·47	32·16	+2·69	−4·20	−1·51
5	38·82	R.	I.	10 39 37·28	38·23	+0·95	−1·28	−0·33	N.	76 33 41·09	46·58	+5·49	−6·80	−1·31
8	38·83	R.	II.	13 4 9·58	10·49	+0·91	−1·27	−0·36	S.	91 37 20·64	28·09	+7·45	−8·46	−1·01
29	38·92	F. B.	I.	7 46 43·70	44·85	+1·15	−1·39	−0·24	N.	66 29 7·35	8·58	+1·23	−1·94	−0·71
31	38·92	R.	I.	9 30 27·77	28·75	+0·98	−1·32	−0·34	N.	71 4 40·36	44·60	+4·24	−5·16	−0·92
Apr. 1	38·93	R.	I.	10 20 20·80	21·68	+0·88	−1·29	−0·41	N.	74 46 58·88	63·41	+4·53	−6·46	−1·93
2	38·93	F. B.	I.	11 9 10·19	11·12	+0·93	−1·27	−0·34	N.	79 13 51·56	57·13	+5·57	−7·50	−1·93

Day, 1890.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Apr. 3	38·94	W.	I.	11 57 27·03	28·18	+1·15	−1·27	−0·12	N.	84 14 48·81	56·43	+7·62	−8·24	−0·62
29	39·04	R.	I.	10 48 42·24	42·99	+0·75	−1·27	−0·52	N.	77 5 33·65	39·50	+5·85	−7·10	−1·25
30	39·04	F. B.	I.	11 36 44·61	45·63	+1·02	−1·26	−0·24	N.	81 53 12·74	20·37	+7·63	−7·99	−0·36
May 1	39·05	W.	I.	12 24 47·32	48·30	+0·98	−1·27	−0·29	N.	87 9 29·05	34·32	+5·27	−8·60	−3·33
2	39·05	R.	I.	13 13 44·07	44·91	+0·84	−1·31	−0·47	N.	92 42 18·69	24·97	+6·28	−8·85	−2·57
11	39·09	R.	II.	22 13 13·09	14·50	+1·41	−1·50	−0·09	N.	106 5 18·34	10·46	−7·88	+7·33	−0·55
26	39·15	F. B.	I.	10 28 43·98	45·01	+1·03	−1·27	−0·24	N.	75 8 58·08	61·87	+3·79	−6·60	−2·81
31	39·17	F. B.	I.	14 32 18·03	19·20	+1·17	−1·41	−0·24	N.	101 4 29·58	37·57	+7·99	−8·41	−0·42
June 6	39·19	W.	II.	20 52 54·41	56·23	+1·82	−1·67	+0·15	N.	111 29 19·07	14·47	−4·60	+5·02	+0·42
26	39·27	W.	I.	13 18 14·32	15·12	+0·80	−1·27	−0·47	N.	93 6 58·65	64·52	+5·87	−8·65	−2·78
27	39·28	R.	I.	14 7 35·84	36·80	+0·96	−1·34	−0·38	N.	98 32 18·93	25·39	+6·46	−8·50	−2·04
July 3	39·30	F. B.	II.	20 23 30·23	32·05	+1·82	−1·77	+0·05	N.	112 46 21·55	17·77	−3·78	+4·05	+0·27
28	39·40	R.	I.	17 31 33·40	34·65	+1·25	−1·72	−0·47	N.	113 19 7·04	10·51	+3·47	−3·32	+0·15
Aug. 1	39·42	R.	II.	22 0 54·60	56·08	+1·48	−1·65	−0·17	N.	107 3 8·74	0·93	−7·81	+7·70	−0·11
5	39·43	R.	II.	1 44 25·32	26·67	+1·35	−1·37	−0·02	N.	83 45 19·64	11·53	−8·11	+9·01	+0·90
7	39·44	W.	II.	3 27 21·00	22·41	+1·41	−1·38	+0·03	N.	73 43 57·18	51·41	−5·77	+6·72	+0·95
23	39·50	R.	I.	16 4 50·19	51·32	+1·13	−1·50	−0·37	N.	109 12 11·18	16·04	+4·86	−6·05	−1·19
29	39·53	W. I. & II.		22 30 12·06	13·72	+1·66	−1·62	+0·04	S.	104 34 34·53	26·19	−8·34	+8·63	+0·29

Day, 1890.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Sept. 4	39·55	F. B.	II.	3 59 52·75	54·25	+1·50	−1·43	+0·07	N.	71 1 44·64	40·07	−4·57	+5·91	+1·34
22	39·62	R.	I.	18 47 44·62	46·06	+1·44	−1·71	−0·27	S.	114 57 4·31	3·69	−0·62	+0·03	−0·59
25	39·64	F. B.	I.	22 0 6·97	8·59	+1·62	−1·62	0·00	S.	107 11 65·54	59·99	−5·55	+7·72	+2·17
27	39·64	F. B.	I.	23 57 11·30	12·83	+1·53	−1·49	+0·04	S.	95 42 25·05	17·76	−7·29	+10·09	+2·80
30	39·66	R.	II.	2 40 47·14	48·27	+1·13	−1·44	−0·31	N.	77 26 9·26	1·21	−8·05	+8·46	+0·41
Oct. 1	39·66	F. B.	II.	3 35 17·80	19·22	+1·42	−1·46	−0·04	N.	72 35 64·19	58·55	−5·64	+6·90	+1·26
21	39·74	R.	I.	20 35 29·12	30·51	+1·39	−1·66	−0·27	S.	112 43 9·27	4·10	−5·17	+4·54	−0·63
28	39·77	W.	II.	3 8 23·42	25·01	+1·59	−1·46	+0·13	N.	74 44 59·34	52·18	−7·16	+7·87	+0·71
Nov. 2	39·79	R.	II.	7 49 25·01	25·99	+0·98	−1·45	−0·47	S.	65 32 43·25	43·38	+0·13	−2·27	−2·14
21	39·86	R.	I.	0 7 28·21	29·64	+1·43	−1·41	+0·02	S.	94 43 49·91	41·14	−8·77	+9·80	+1·03
24	39·88	W.	I.	2 44 32·89	34·13	+1·24	−1·43	−0·19	S.	76 59 60·35	52·69	−7·66	+8·42	+0·76
25	39·88	W.	I.	3 38 44·83	46·13	+1·30	−1·47	−0·17	S.	72 11 20·62	15·59	−5·03	+6·96	+1·93
26	39·88	R.	II.	4 34 34·79	35·82	+1·03	−1·51	−0·48	S.&N.	68 24 47·36	42·74	−4·62	+5·10	+0·48
Dec. 25	40·00	W.	I. & II.	6 5 48·64	50·09	+1·45	−1·53	−0·08	N.	65 2 56·44	54·04	−2·40	+1·62	−0·78
						s		s				″		′
Mean of Errors, without regard to sign ...					...	**1·191**	...	**0·256**		...	...	**5·297**	...	**1·208**
Mean Errors for the Year					...	**+1·191**	...	**−0·233**						

TABLE II.

Radcliffe Observations of the Moon, 1890.

Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance, **Uncorrected** *and* **Corrected** *for the Change in the Unit of Mean Time introduced in the year* 1864.

Day, 1890.	Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Errors of Longitude (Hansen *minus* Observed). Corrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Uncorrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Corrected.
				″	″	″	″
Jan. 8	R.	II.	S.	+13·09	−6·08	+0·41	+1·61
Jan. 29	F.B.	I.	S.	+15·65	−3·89	+1·16	+2·72
Feb. 3	F.B.	I.	N.	+14·49	−4·65	−1·74	−0·26
5	R.	II.	S.	+14·44	−5·11	+0·19	+1·18
9	R.	II.	S.	+14·98	−5·71	+2·90	+2·31
12	R.	II.	S.	+15·37	−6·77	+0·82	−0·89
Feb. 27	W.	I.	S.	+13·98	−5·26	−1·93	−0·22
Mar. 3	W.	I.	N.	+15·49	−3·80	−1·70	−0·47
5	R.	I.	N.	+14·95	−4·97	−0·12	+0·60
8	R.	II.	S.	+15·49	−5·38	+1·64	+1·14
Mar. 29	F.B.	I.	N.	+15·80	−3·38	−1·61	−0·11
31	R.	I.	N.	+14·57	−4·88	−0·38	+0·65
Apr. 1	R.	I.	N.	+13·56	−6·25	−0·39	+0·35
2	F.B.	I.	N.	+14·85	−5·39	−0·22	+0·18
3	W.	I.	N.	+18·85	−1·90	+0·13	+0·15
Apr. 29	R.	I.	N.	+12·41	−7·53	+1·24	+1·73
30	F.B.	I.	N.	+17·01	−3·43	+0·98	+1·09
May 1	W.	I.	N.	+15·69	−5·35	−0·98	−1·34
2	R.	I.	N.	+14·09	−7·52	+1·14	+0·29
11	R.	II.	N.	+21·90	−1·02	−0·10	−0·98
May 26	F.B.	I.	N.	+15·33	−4·28	−1·97	−1·33
31	F.B.	I.	N.	+18·91	−3·49	+2·18	+0·71
June 6	W.	II.	N.	+25·74	+1·90	+2·49	+0·97
June 26	W.	I.	N.	+13·37	−7·60	+0·92	+0·08
27	R.	I.	N.	+15·64	−6·02	+1·25	−0·01
July 3	F.B.	II.	N.	+25·44	+0·61	+2·22	+0·42

Day, 1890.	Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude Hansen (*minus* Observed). Uncorrected.	Corrected.	Errors of E.N.P.D. Hansen (*minus* Observed). Uncorrected.	Corrected.
July 28	R.	I.	N.	+17″·36	−6″·46	+2″·62	+0″·47
Aug. 1	R.	II.	N.	+22·70	−2·26	+0·03	−0·95
5	R.	II.	N.	+21·75	−0·60	−0·34	+0·73
7	W.	II.	N.	+21·13	+0·18	−0·61	+1·03
Aug. 23	R.	I.	N.	+16·65	−5·37	+1·67	−0·15
29	W.	I. & II.	S.	+25·57	+0·43	+1·15	+0·48
Sept. 4	F.B.	II.	N.	+21·78	+0·71	−0·23	+1·51
Sept. 22	R.	I.	S.	+19·58	−3·61	+1·01	−0·89
25	F.B.	I.	S.	+23·78	−0·75	+2·83	+2·03
27	F.B.	I.	S.	+23·95	−0·58	+2·45	+2·81
30	R.	II.	N.	+18·25	−4·45	−2·60	−1·00
Oct. 1	F.B.	II.	N.	+21·09	−0·85	−0·72	+1·09
Oct. 21	R.	I.	S.	+19·98	−3·79	−0·17	−1·55
28	W.	II.	N.	+24·10	+1·62	−0·63	+1·20
Nov. 2	R.	II.	S.	+13·41	−6·71	−2·33	−0·92
Nov. 21	R.	I.	S.	+23·27	−0·14	+0·48	+1·07
24	W.	I.	S.	+19·61	−2·88	−1·85	−0·11
25	W.	I.	S.	+19·22	−2·81	−0·59	+1·31
26	R.	II.	S. & N.	+14·91	−6·70	−2·47	−0·50
Dec. 25	W.	I. & II.	N.	+19·70	−1·10	−2·57	−0·77
Mean of Errors, without regard to sign				**18″·019**	**3″·786**	**1″·264**	**0″·921**
Mean Errors for Year				**+18″·019**	**−3″·549**	...	...

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F.B., Mr. F. A. Bellamy.

TABLE III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 *to* 1890, *as Computed from Hansen's Tables.*

Uncorrected *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1864.

Year.	Errors of Longitude (Hansen *minus* Observed).	
	Uncorrected.	**Corrected.**
	″	″
1847	+ 0·51	+ 0·51
1848	− 0·53	− 0·53
1849	− 1·08	− 1·08
1850	− 0·97	− 0·97
1851	− 1·93	− 1·93
1852	− 1·57	− 1·57
1853	− 2·18	− 2·18
1854	− 2·34	− 2·34
1855	− 1·40	− 1·40
1856	− 1·51	− 1·51
1857	− 2·41	− 2·41
1858	− 2·61	− 2·61
1859	− 2·49	− 2·49
1860	− 3·62	− 3·62
1861	− 2·95	− 2·95
1862	− 2·83	− 2·83
1863	− 1·61	− 1·61
1864	+ 0·12	− 0·81
1865	+ 1·27	− 0·22
1866	+ 2·14	− 0·22
1867	+ 3·48	+ 0·36
1868	+ 4·12	+ 0·28
1869	+ 4·28	− 0·35
1870	+ 4·83	− 0·66
1871	+ 6·96	+ 0·44
1872	+ 7·31	+ 0·10
1873	+ 8·24	+ 0·20
1874	+ 9·29	+ 0·56
1875	+ 9·87	+ 0·36
1876	+ 9·80	− 0·50
1877	+ 9·23	− 1·90
1878	+ 8·22	− 3·60
1879	+ 9·63	− 3·12
1880	+ 10·89	− 2·77
1881	+ 10·51	− 4·06
1882	+ 12·68	− 2·51
1883	+ 14·71	− 1·50
1884	+ 14·65	− 1·91
1885	+ 15·20	− 1·82
1886	+ 15·34	− 2·53
1887	+ 15·70	− 3·25
1888	+ 17·68	− 2·46
1889	+ 17·37	− 3·51
1890	+ 18·02	− 3·55

1847 to 1879: Greenwich observations. 1880 to 1882: Mean of Greenwich and Radcliffe. 1883 to 1890: Radcliffe observations.

Radcliffe Observatory, Oxford:
1891 *June* 10.

Preliminary Note on the Change of Personal Equation with Stellar Magnitude in Transits observed with the Transit Circle at the Royal Observatory, Greenwich. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

The question of the determination of the variation of personal equation with the magnitude of the star observed has been lately brought prominently forward by Professor Auwers in connection with the Greenwich observations of *Victoria* and *Sappho* and comparison stars in 1889, now being discussed by him. I had hoped to have used the Personal Equation Machine for this investigation, this being one of the objects for which it was originally intended, but as special photometric arrangements would have to be devised, it was judged best, in order to avoid delay, to determine the change of personal equation in observations of stars with the transit circle, when screens of fine wire gauze were placed in front of the object-glass to obscure the stars' light. The screens used were marked *a*, *b*, *e*, *f*, and *g*, the first three being made of fine brass wire, and the last two of coarser iron wire. The size of the meshes, which are approximately square, and the thickness of the wires, were measured with a micrometer microscope for each of these screens, and the results are given in the following table.

	Screen *a*.	*b*.	*e*.	*f*.	*g*.
	mm.	mm.	mm.	mm.	mm.
Side of squares of mesh...	0·45	0·52	0·39	1·08	1·21
Thickness of wire ...	0·12	0·13	0·13	0·34	0·30

As the star entered the field of the telescope, the object-glass was covered successively by one or other of these screens, or by two screens superposed, the observer then making estimations of the apparent magnitude of the stars, whose light was thus diminished. The accuracy of these estimations was tested by the comparison of the magnitude given in the Greenwich Ten-Year Catalogue, or in the British Association Catalogue, with similar estimations of magnitude, either (1) with the object-glass unscreened, when the estimated magnitude should agree with the tabular, or (2) when card diaphragms, with circular apertures of $5\frac{1}{8}$ and $3\frac{1}{4}$ inches diameter respectively, were placed over the object-glass, so that the estimated magnitudes should differ by 1·0 and 2·0 magnitudes respectively from the tabular. The mean results of these estimations for each observer, and for each screen, diaphragm, or pair of screens, are given in Table I. It will be seen from the estimations with full aperture, and with diaphragms *c* and *d*, that all the observers agree in estimating the magnitude as numerically too large, and that

this excess is larger the smaller the apparent star is. We may say from this that the screens a, b, and e each diminish the brightness by between 1·5 and 2·0 magnitudes.

As a star approached the transit wires, the object-glass was covered with a screen, and the transit recorded over the first four wires; the screen was then removed, and the transit over the last four wires was recorded with full aperture of object-glass. For the next star the order of these operations was reversed, that is, the first four wires were observed with full aperture, and the last four with the screen. The excess of the time of transit, reduced to centre wire, with screened object-glass over the time with unscreened, was then tabulated. The means of the results of these observations for each observer, and for each screen or pair of screens, are given in Table II. Since it appears from Table I. that the values of screens a, b, and e are approximately the same, as are also those of f and g, the observations by each observer with screens a, b, and e, with f and g, and with the pairs $\overline{a+b}$, $\overline{a+e}$, $\overline{b+e}$ have been taken together, and then grouped according to the magnitudes of the stars observed. The results of this grouping are given in Table III. As far as they go they indicate that there is a general tendency with all the observers to observe stars with object-glass screened later, and that this is more marked in the case of the fainter stars. It will be remarked that the general mean, when the brightness is reduced nearly four magnitudes by means of two screens, is less than the general mean when only one screen is used, instead of being nearly double, as it should be theoretically. The comparative paucity of observations with two screens superposed may, to some extent, account for this anomalous result, but it is not unlikely that the observers may have been influenced by the peculiar character of the diffraction image equally with one screen and with two. It is not clear that the results indicate a real change of personal equation in observations of fainter stars, as the introduction of the screen modifies the image of the star, and this modification of the image may give rise to a change of personal equation unconnected with the diminution of brightness.

TABLE I.

Table of Difference of Estimated and Tabular Magnitudes by each Observer when the Star is seen with full aperture and with each diaphragm and each screen.

	No. of Obs.	A.D. Mag.	No. of Obs.	T. Mag.	No. of Obs.	L. Mag.	No. of Obs.	H. Mag.	Means Mag.
Full aperture	89	+0·20	67	+0·37	103	+0·08	157	+0·05	+0·14
Screen *a*	65	+2·46	40	+2·15	93	+1·76	97	+2·00	+2·05
Screen *b*	59	+2·15	44	+2·00	88	+1·51	97	+1·79	+1·81
Screen *e*	51	+2·68	43	+2·16	93	+1·98	75	+2·11	+2·18
Screen *f*	23	+1·91	7	+1·24	7	+1·43	16	+1·49	+1·63
Screen *g*	20	+1·86	8	+1·23	7	+1·14	18	+1·52	+1·55
Screen $\overline{a+b}$	18	+3·99	24	+3·80	27	+3·28	23	+3·73	+3·66
Screen $\overline{a+e}$	8	+4·20	21	+3·75	25	+3·67	6	+4·32	+3·83
Screen $\overline{b+e}$	4	+3·78	20	+3·80	26	+3·44	6	+3·65	+3·62
Diaphragm *c* $3\frac{1}{4}$ inches...	53	+2·56	36	+2·33	80	+1·88	85	+2·07	+2·15
Diaphragm *d* $5\frac{1}{8}$ inches...	61	+1·54	39	+1·74	87	+1·17	94	+1·21	+1·34

TABLE II.

Excess of Observed Time of Transit with Screen over Observed Time with Full Aperture.

Observer.	Screen *a*. No. of Obs.	s	Screen *b*. No. of Obs.	s	Screen *e*. No. of Obs.	s	Screen $\overline{a+b}$. No. of Obs.	s	Screen $\overline{a+e}$. No. of Obs.	s
A.D.	27	+0·027	26	+0·020	20	+0·016	5	+0·030	1	+0·050
T.	11	+0·034	9	+0·036	12	+0·062	7	+0·057	6	+0·007
L.	20	+0·026	23	+0·013	13	+0·053			3	−0·040
H.	38	+0·036	41	+0·036	24	+0·028	5	+0·064	2	−0·005
Means		+0·031		+0·026		+0·035		+0·051		−0·003

Observer.	Screens $\overline{b+e}$. No. of Obs.	s	Screens $\overline{a+b+e}$. No. of Obs.	s	Screen *f*. No. of Obs.	s	Screen *g*. No. of Obs.	s
A.D.	3	−0·013	1	+0·020	7	0·000	4	+0·023
T.	4	+0·048	2	+0·050			2	−0·040
L.	2	−0·060			1	0·000		
H.					7	+0·004	5	+0·056
Means		+0·004		+0·040		+0·002		+0·027

TABLE III.

Excess of Observed Time of Transit with Screen over Observed Time with Full Aperture arranged according to Magnitude of Star.

Screen *a*, *b*, or *e* diminishing the brightness by nearly 2 magnitudes.

Magnitude of Stars.	A.D. No. of Obs.	Mean Diff. s	T. No. of Obs.	Mean Diff. s	L. No. of Obs.	Mean Diff. s	H. No. of Obs.	Mean Diff. s
0−3·9	14	+0·036	5	+0·022	11	−0·007	6	+0·015
4·0−4·9	13	+0·022	8	+0·016	10	+0·035	9	+0·034
5·0−5·9	22	+0·014	13	+0·064	30	+0·039	25	+0·023
6·0−6·9	14	+0·013	4	+0·067	4	+0·008	38	+0·033
7·0 and fainter	8	+0·051	1	+0·070	1	+0·020	24	+0·052
Means	71	+0·024	31	+0·045	56	+0·025	102	+0·034

General Mean +0s·031.

Screens $\overline{a+b}$, $\overline{a+e}$, or $\overline{b+e}$ diminishing the brightness by about 3·7 magnitudes.

Magnitude of Stars.	A.D. No. of Obs.	Mean Diff. s	T. No. of Obs.	Mean Diff. s	L. No. of Obs.	Mean Diff. s	H. No. of Obs.	Mean Diff. s
0−3·9	6	−0·023	5	+0·036	2	−0·045	2	−0·005
4·0−4·9	3	+0·100	5	+0·064	3	−0·050	3	+0·030
5·0 and fainter			7	+0·022			2	+0·115
Means	9	+0·018	17	+0·038	5	−0·048	7	+0·044

General Mean +0s·023.

The Motion of 20 Draconis. By S. W. Burnham.

Although this double star (Σ 2118) was discovered by William Herschel more than one hundred years ago, it has received but little attention from observers in recent years. Within the last thirty years it has been close and rather difficult, but before 1860 it was easily measurable with almost any telescope. During this period the distance was slowly diminishing, while the angle remained nearly constant. For the past ten years it has been too close to be seen with any but the most powerful refractors.

I have collected all the observations with the micrometer which have any value, and give them below in chronological order for convenience in future investigations. I have omitted all negative results where the star was noted as "round," "single," "elongated," &c., since it is evident that it has never been really single, and the failures to see it were due to insufficient optical power, or unfavourable atmospheric conditions.

1783·26	251°·5	...	H	1*n*
1830·32	242·6	0·63	H	1*n*
1831·37	246·1	0·70	H	1*n*
1832·30	246·4	0·85	Σ	5*n*
1834·57	252·0	...	Da	1*n*
1836·75	247·0	0·71	Σ	3*n*
1840·77	242·9	...	Da	1*n*
1841·24	245·3	0·77	OΣ	3*n*
1843·32	248·4	0·8	Ma	1*n*
1847·71	243·3	...	Mh	2*n*
1847·97	244·6	0·65	Ma	2*n*
1854·81	241·7	0·61	Da	3*n*
1857·35	240·1	0·37	Se	3*n*
1859·67	235·7	0·58	OΣ	2*n*
1872·42	238·0	0·27	OΣ	1*n*
1874·73	224·0	...	N	1*n*
1877·13	229·4	0·28	De	3*n*
1880·82	211·3	0·20	β	4*n*
1889·45	140·7	0·11	β	3*n*
1891·33	125·6	0·11	β	3*n*

All of these measures are laid down accurately to scale on the accompanying diagram, except the observations of Herschel, Dawes, Mitchell, and Newcomb, where the distance was not measured. It is obvious at a glance that these positions taken together furnish no evidence whatever of orbital motion so far

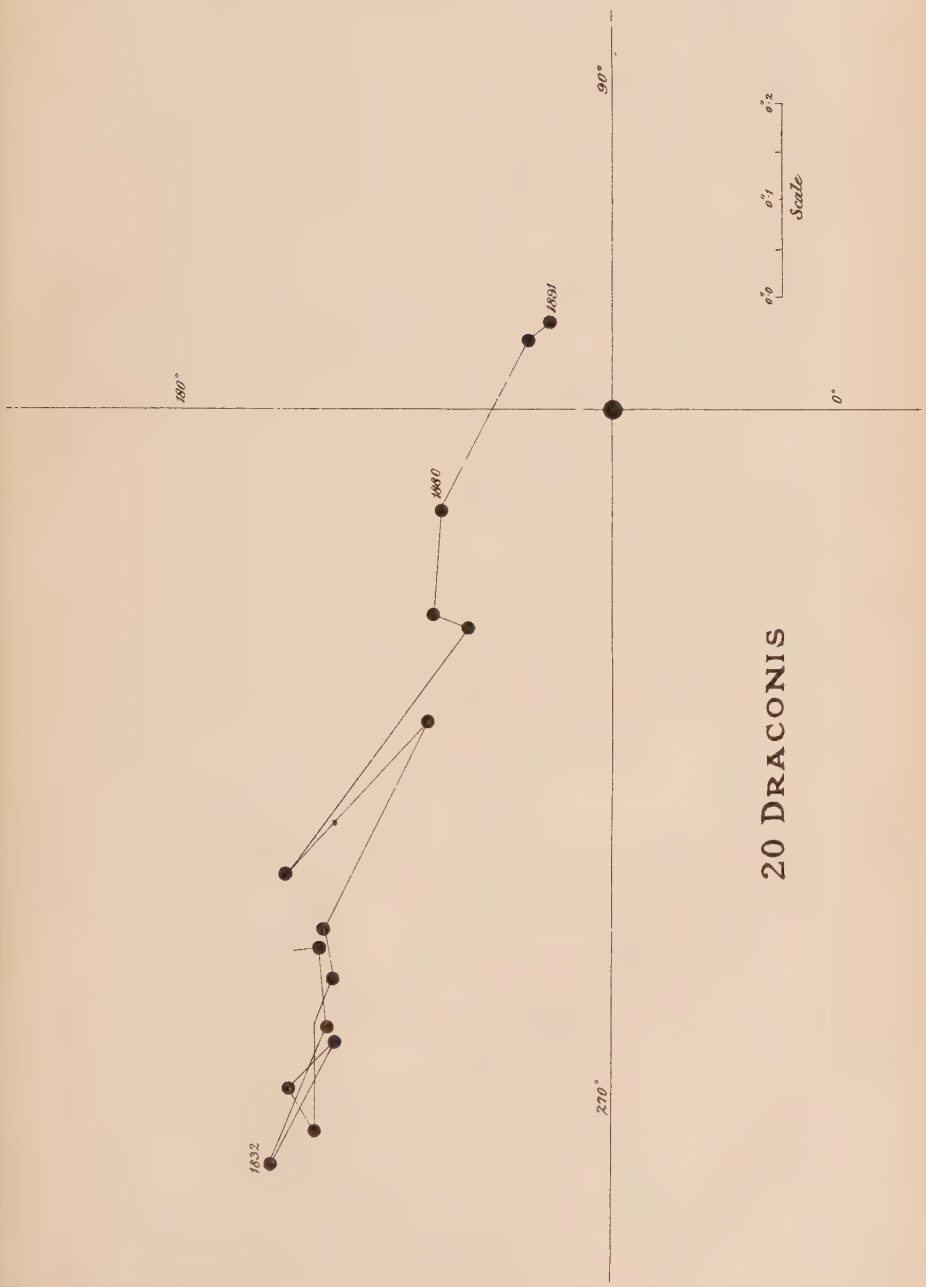
as their direction is concerned. A straight line will better represent them than any curve. The chances are enormously in favour of this being a physical system, and I have no doubt that will be shown to be the fact, but at present it is more a matter of probability than anything else. If these stars were a considerable distance apart, there would be hardly any doubt that the relative movement was due to proper motion. The two components, as one star, have a proper motion of 0″·227 in the direction of 79°·3, and this angle corresponds very nearly to the motion of B with respect to A. A line drawn through the observed positions of B, making an angle of 73° with the meridian, will represent the measures as closely as they are ever represented by a line of any character in stars of this class. To be sure, the later observations appear to indicate an accelerated motion, as would be expected if the path is a very elongated ellipse, but the errors in the series generally are so large it is impossible to deduce any harmonious result. Taking the mean of Struve's measures to represent the place of B at the mean date (1834·5), the movement of that star to 1891·3 is 0″·86, giving an average of 0″·015 per annum. If it is moving around the primary, as is most probably the case, it is evident that the apparent ellipse is one of extraordinary elongation. There is nothing like it known in the heavens. The period is certainly several hundred years. In one or two years more, the measures will definitely settle the character of this motion. It will probably be a difficult object for some time to come, and should be carefully measured by observers having sufficiently powerful instruments.

It will be noticed that the same grouping of positions, and apparent reversal of motion, occurs here in the first eight measures, which I have shown elsewhere is found in the measured places of all slow-moving pairs.

Lick Observatory:
May 29.

The Companions to Regulus. By S. W. Burnham.

The distant companion to *Regulus* was first observed by Herschel I. in 1779, and catalogued as No. 11 of his Class VI. It was measured on one night, but the distance was about 8″ too small. In 1821 it was better observed by South and Herschel, but the accurate measures commence with the observations of Struve a few years later. The measures of the last fifty years show conclusively that this companion has the same proper motion as *Regulus*, which has a motion in space of 0″·267 annually in the direction of 274°·5. Since the measures of Struve



20 DRACONIS

S.W.Burnham, del.

Spottiswoode & Co Lith. London.

the large star has shifted its place nearly 14″. The following measures are sufficient to show the relative fixity of the two stars:

1781·84	305°·1	168″·33	H 1*n*
1821·21	307·3	174·90	Sh 2*n*
1836·24	306·6	176·90	Σ 5*n*
1863·18	306·8	176·06	En 3*n*
1864·78	306·6	176·89	De 5*n*
1891·34	306·8	176·73	β 4*n*

Winlock, when at the Harvard College Observatory, found that the old companion had a very minute attendant, which had escaped all previous observers. He does not seem to have measured it, and the first observation with the micrometer is in 1877 by Hall. The following are all the measures to this time:—

1877·75	86°·4	3″·48	Hl 5*n*
1878·14	88·5	3·29	β 4*n*
1880·15	87·7	3·03	β 1*n*
1890·27	85·7	3·05	β 3*n*
1891·34	88·2	3·05	β 3*n*

These observations show that there has been no change in the angle during this time, and probably none in the distance, and, therefore, the new companion is moving through space with the other stars, and the whole probably form one vast system. During the period covered by these measures, B has moved 3″·3 by virtue of its proper motion, and the distance of C at the end of this time would be increased by that amount provided the movement was not common to both stars.

With most telescopes the close pair would be difficult. My first two sets of measures were made with the Chicago 18½-inch refractor. Clark has seen it with a 12-inch object-glass, and that is probably about as small an aperture as it could be fairly seen with. In the course of time there will doubtless be some indications of orbital motion in B and C, but the distance between them is too large for any rapid movement.

Lick Observatory, May 15.

The Orbit of 36 *Andromedæ* (Σ 73). By T. Lewis.

					h	m	s	
R.A.	...	...	...	...	0	50	4	1890·0
N.P.D.	...	...	...	...	66°	58′	″3	

Some time ago, having drawn the apparent ellipse for this binary, I was surprised to find that the companion had passed ap-astron. According to Doberck's elements, computed in 1875, this should not occur till 1973. Collecting all the published observations, I carefully plotted them on millimètre paper, and found that a satisfactory curve could not be drawn through them. By comparing neighbouring observations, a systematic difference between the observers was very apparent. The final personal equations deduced were :—

H_2.	−0°·5 and	″·00	Ta.	+1°·5 and	+0″·3
Σ.	−0·5 „	·00	Har.	−0·5 „	−·05
Sm.	−0·5 „	−·02	Gld.	+0·6 „	+·05
Md.	−1·4 „	−·02	Dob.	−0·3	...
Da.	+1·2 „	+·05	Sch.	−0·3	...
OΣ.	0·0 „	−·05	W. & S.	−0·5 „	+·04
De.	+0·7 „	+·05	Hall.	−0·5	...
Sec.	−0·3 „	+·10	Eng.	+0·2 „	−·05

The quantities are applicable to the observations with the given sign. For other observers an equation either could not be deduced or the material was insufficient. After correcting the position-angles for precession to 1890, and also for the P.E.'s, they were again plotted and a curve drawn, from which an ellipse was computed according to the method of Herschel. These elements were then corrected by Klinkerfues' method and the definitive elements obtained.

P	137·5 years	Ω	123° 33′ (1890·0)
T	1819·7	λ	70° 0′
ϵ	0·67	a	1″·09
γ	44° 30′	μ	2°·62

Doberck's period is 349 years.

Below is a comparison between the observations as corrected for P.E. and precession, and those computed from the above elements.

Epoch.	O	C	O−C	O	C	O−C	Observer.
	°	°	°	″	″	″	
1830·67	302·0	302·8	−0·8	0·72	0·81	−·09	H_2.
30·78	306·8	3·1	+3·7	·90	·81	+·09	H_2.
31·79	308·3	5·5	+2·8	·78	·83	−·06	H_2.
32·14	307·5	307·0	+0·5	0·85	·84	+·01	Σ.
35·92	315·4	313·7	+1·7	1·08	·93	+·15	Sm.
36·98	318·8	315·8	+3 0	0 94	0·96	−·02	Σ.
39·77	318·2	320·4	−2·2	1·08	1·04	+·04	Sm.
39·79	319·2	0·4	−1·2	1·14	·04	+·10	Da.
40·35	321·2	1·3	−0·1	1·05	·05	·00	Md.
40·98	320·7	2·1	−1·4	1·13	·07	+·06	Da.
41·59	323·5	2·8	+0·7	1·17	·08	+·09	Md.
41·64	322·2	323·1	−0·9	1·15	1·09	+·06	OΣ.
41·87	322·6	323·4	−0·8	1·13	1·10	+·03	Da.
42·34	323·6	3·8	−0·2	0·99	1·11	−·12	Ka.
42·77	324·5	4·3	+0·2	1·03	1·12	−·09	Md.
42·94	324·2	4·5	−0·3	1·06	1·12	−·06	Da.
43·12	322·6	4·8	−2·2	0·98	1·14	−·16	Sm.
43·92	324·8	5·8	−1·0	1·17	1·18	−·01	Da.
46·78	329·0	9 0	0·0	1·21	1·19	+·02	OΣ.
46·93	330·2	9·2	+1·0	1·17	1·19	−·02	Da.
46·99	327·8	9·3	−1·5	1·24	1·20	+·04	Md.
47·68	330·4	330·1	+0·3	1·05	1·20	−·15	Mit.
47·89	328·3	0·2	−1·9	1·21	1·21	·00	Md.
47·92	331·1	0·3	+0·8	1·28	1·23	−·05	Da.
50·91	333·3	3·4	−0·1	1·22	1·23	−·01	Da.
51·00	332·2	3·6	−1·4	1·37	1·24	+·13	Md.
51·78	335·1	4·3	+0·8	1·29	1·24	+·05	Md.
51·94	336·6	4·5	+2·1	1·11	1·24	−·13	Flt.
52·60	334·3	5·1	−0·8	1·33	1·25	+·08	Md.
52·69	333·8	5·2	−1·4	1·32	1·25	+·07	OΣ.
52·83	335·4	5·3	+0·1	1·28	1·25	+·03	Sm.
53·09	335·8	5·6	+0·2	1·41	1·26	+·15	Md.
53·89	336·4	6·5	−0·1	1·21	1·26	−·05	Da.
53·96	338·1	6·6	+1·5	1·18	1·27	−·09	J.
54·69	338·3	7·3	+1·0	1·24	1·28	−·04	OΣ.
54·75	337·1	7·4	−0·3	1·28	1·28	·00	Da.
54·91	340·2	7·5	+2·7	1·25	1·28	−·03	Mor.
55·29	335·3	7·7	−2·2	1·35	1·28	+·07	Md.
55·52	335·8	7·9	−2·1	1·30	1·28	+·02	De.

Epoch.	O	C	O−C	O	C	O−C	Observer.
	°	°	°	″	″	″	
1855·99	336·1	338·4	−2·3	1·18	1·28	−·10	De.
56·09*	344·3	8·5	+5·8	1·30	1·28	+·02	Win.
56·61	338·0	9·1	−1·1	1·25	1·29	−·04	De.
56·73	338·5	9·2	−0·7	1·32	1·29	+·03	OΣ.
56·97	338·9	9·3	−0·4	1·25	1·29	−·04	De.
57 03	339·2	339·4	−0·2	1·29	1·29	·00	Sec.
57·75	339·1	340·0	−0·9	1·37	1·30	+·07	Md.
57·84	338 3	0·1	−1·8	1·17	1·30	−·13	Sec.
58·04	338·8	0·3	−1·5	1·32	1·31	+·01	Md.
59·36	343 3	1·6	+1·7	1·23	1·32	−·09	Md.
59·83	341·5	2·0	−0·5	1·24	1·32	−·08	Da.
59·89	340 2	2·1	−1·9	1·34	1·33	+·01	Md.
60·83	343·9	2·8	+1·1	1·42	1·33	+·09	Md.
61·74	344·2	3·6	+0·6	1·30	1·34	−·04	OΣ.
61·81	342·3	3·7	−1·4	1·34	1·34	·00	Md.
62·78	344·8	4·3	+0·5	1·17	1·35	−·18	De.
62·83	344·5	4·4	+0·1	1·31	1·35	−·04	Md.
63·83	345·2	5·5	−0·3	1·22	1·35	−·13	De.
64·77	345·8	6·4	−0·6	1·27	1·36	−·09	De.
65·11	348·9	6·6	+2·3	1·57	1·36	+·21	Eng.
65·65	346·6	7·0	−0·4	1·26	1·36	−·10	De.
65·69	344·9	7·1	−2·2	1·35	1·36	−·01	Knott.
65·73	348·6	7·2	+1·4	1·10	1·36	−·26	Ta.
66 05	349·3	7·4	+1 9	1·41	1·36	+·05	Sec.
66·74	349·8	7·9	+1·9	1·46	1·37	+·09	Har.
66·81	347·8	8·0	−0·2	1·17	1·37	−·20	De.
66·83	345·8	8·0	−2·2	1·41	1·37	+·04	Ta.
67·03	351·0	8·2	+2·8	1 25	1·37	−·12	Ka.
67·70	348·5	8·7	−0·2	1·29	1·37	−·08	De.
68·41	349·4	9·3	+0·1	1·17	1·37	−·20	Har.
68·66	350·7	9·5	+1·2	1·44	1·37	+·07	De.
68·76	350·8	349·6	+1·2	1·57	1·37	+·20	Br.
69·66	350·3	350·6	−0·3	1·36	1·38	−·02	De.
69·72	351·1	0·6	+0·5	...	...	...	Ta.
69·86	349·1	0·8	−1·7	1·35	1·38	−·03	Har.
70·14	350·6	0·9	−0·3	1·25	1·38	−·13	Gld.
70·35	350·5	1·0	−0·5	1·27	1·38	−·11	De.
70·60	350 9	1·2	−0·3	1·35	1·38	−·03	Gld.

* A single observation, apparently 5° in error.

Epoch.	O	C	O−C	O	C	O−C	Observer.
	°	°	°	″	″	″	
1871·60	353·5	352·0	+1·5	1·25	1·38	−·13	Gld.
71·62	353·2	2·0	+1·2	1·47	1·38	+·09	De.
72·03	351·9	2·4	−0·5	1·40	1·39	+·01	W. & S.
72 65	353·3	2·8	+0·5	1·40	1·39	+·01	De.
72·86	349·0	3·0	−4·0	1·27	1·39	−·12	Ta.
72 88	354·1	3·0	+1·1	1·22	1·39	−·17	W. & S.
73·68	353·1	3·8	−0·7	1·41	1·39	+·02	De.
73·81	352·7	3·9	−1·2	1·38	1·39	−·01	W. & S.
73·86	353·2	4·0	−0·8	1·32	1·39	−·07	Ta.
73·91	353·6	4·0	−0·4	1·45	1·39	+·06	Gld.
74·04	355·8	4·1	+1·7	1·±	1·39	...	Nobile.
74·80	355·2	4·7	+0·5	1·32	1·38	−·06	De.
74·94	355·5	4·8	+0·7	1·45	1·38	+·07	W. & S.
75·54	355·9	5·3	+0·6	1·42	1·38	+·04	W. & S.
75·62	356·5	5·4	+1·1	1·30	1·38	−·08	De.
75·70	356·2	5·5	+0·7	1·42	1·38	+·04	Du.
76 00	358·1	5·8	+2·3	1·34	1·38	−·04	Hall.
76·07	355·4	5·8	−0·4	...	...	...	Gld.
76·08	359·0	5·8	+3·2	...	...	...	Dob.
76·75	354·7	6·4	−1·7	1·16	1·37	−·21	Dob.
76·78	356·7	6·4	+0·3	1·43	1·37	+·06	De.
76·95	358·1	6·5	+1·6	1·32	1·37	−·05	W. & S.
77·02	355·9	6·6	−0·7	1·28	1·37	−·09	Sp.
77·02	355·6	6·6	−1·0	1·28	1·37	−·09	Sch.
77·19	358·2	6·8	+1·4	1·49	1·37	+·12	Pl.
77·52	357·1	7·0	+0·1	1·37	1·37	·00	De.
77·62	356·0	7·0	−1·0	...	1·37	...	Gld.
77·94	358·3	7·4	+0·9	1·37	1·37	·00	W. & S.
78·45	357·8	7 7	+0·1	...	1·36	...	Gld.
78·87	356·4	8·2	−1·6	1·33	1·36	−·03	Hall.
78·90	357·6	8·2	−0·6	1·20	1·36	−·16	Dob.
79·86	360·5	8·8	+1·7	...	1·36	...	Dob.
80·11	359·5	9·1	+0·4	1·38	1·36	+·02	Jed.
80·89	359·8	359·6	+0·2	1·32	1·35	−·03	Dob.
82·01	360·9	360·6	+0·3	1·34	1·34	·00	Schi.
82·10	360·6	0·7	−0·1	1·36	1·34	+·02	Eng.
82·81	361·8	1·5	+0·3	1·32	1·33	−·01	Dob.
83·02	361·2	1·6	−0·4	1·37	1·33	+·04	Eng.
83·16	363·1	1·7	+1·4	1·51	1·33	+·18	Seab.

Epoch.	O	C	O−C	O	C	O−C	Observer.
	°	°	°	″	″	″	
1883·32	361·2	361·8	−0·6	1·41	1·33	+·08	Eng.
83·86	361·7	1·8	−0·1	1·27	1·32	−·05	Per.
84·12	361·9	2·1	−0·2	1·27	1·31	−·04	Eng.
85·25	364·1	3·1	+1·0	1·35	1·30	+·05	Schi.
85·28	362·0	3·1	−1·1	1·15	1·30	−·15	Per.
87·01	365·2	5·1	+0·1	1·15	1·28	−·13	Schi.
88·05	367·4	6·1	−1·3	1·18	1·27	−·09	Schi.
88·51	366·1	6·6	−0·5	1·21	1·26	−·05	Lev.
1891·08	369·2	368·8	+0·4	1·35	1·25	+·10	Maw.*

Proper Motions of Twenty Southern Stars.

By J. L. E. Dreyer, Ph.D.

In the *Monthly Notices* for May 1886 I discussed the Proper Motions of twenty-nine telescopic stars occurring in the Second Armagh Catalogue of Stars. In the present paper I have put together the positions from all available sources of twenty stars which seem endowed with proper motion, which (with two exceptions) has not been noticed before, at least so far as I am aware.

These stars are all situated in the region covered by the southern *Durchmusterung*, viz. between 2° and 23° south declination. In 1881 the late Professor Schönfeld suggested to me to observe about nine hundred stars, of which the earlier observations differed considerably *inter se* or from the Bonn zones. These stars were accordingly observed with the Dunsink Meridian Circle by myself, and afterwards by Mr. Rambaut, and the resulting places for 1885 were published in part vi. of the *Dunsink Observations*. I have recently examined the more remarkable cases which might arise from proper motion, but only in twenty cases could such be established with certainty, while a number of other cases must be deferred until further observations have been obtained. I have also passed over a number of stars the proper motions of which have been determined elsewhere.

As the materials were rather scanty, and will ere long be considerably improved by the publication of the Paris Catalogue and the southern zone-work of the Astronomische Gesellschaft, I have not applied any of the so-called systematic corrections to

* The last measure, a mean of three nights, was kindly made for me by Mr. W. H. Maw, for comparison after the orbit was computed. The angle agrees well with that computed.

the various catalogues. All the places were reduced to 1875 with Struve's constant, and where there were more than three different epochs the proper motion was deduced by the method of least squares. Lalande's and Bessel's observations were reduced anew with Von Asten's and Luther's tables. The new editions of Argelander's (Oeltzen's) and Lamont's catalogues were used.

S.D. −12°, 20; Magn. 8·3.

		h m s	° ′ ″	
Bessel	1823·8	0 7 37·18	−11 59 50·8	(1 obs.)
Greenwich 6-Year	1852·9	37·72	57·3	(1)
„ 7-Year	1854·9	37·73	57·1	(3)
Santini	1857	37·90	56·1	(2)
Yarnall	1862·0 and 60·5	37·88	57·9	(2, 3)
Schjellerup	1863·0	37·89	59·4	(1)
Königsberg (*A.N.* 1804)	1869·9	38·27	63·0	(2)
Dunsink	1882·5	38·65	62·7	(3)

Giving Bessel, Six-Year Cat., Schjellerup and Königsberg half-weight, the P.M. is found = + 0ˢ·0218 and −0″·172, with which these places become:

	h m s	° ′ ″
Bessel	0 7 38·30	−11 59 59·6
6-Year	38·20	61·1
7-Year	38·17	60·6
Santini	38·29	59·2
Yarnall	38·16	60·4
Schjellerup	38·15	61·5
Königsberg	38·38	63·9
Dunsink	38·49	61·4

S.D. −7°, 603; Magn. 8·2.

		h m s	° ′ ″	
Lalande	1796·7	3 22 7·15	−6 57 18·4	(1)
Bessel	1824·9	8·30	25·7	(1)
Paris	1860·5 and 1862·0	9·03	31·4	(2, 1)
Dunsink	1882·0	9·73	36·2	(2)

The P.M. in R.A. has been remarked by M. Bossert, but the new reduction of Bessel's observation clearly shows that there is also motion in declination. With P.M. = + 0ˢ·0299 and −0″·206 the observed places become:

	h m s	° ′ ″
Lalande	3 22 9·49	−6 57 34·5
Bessel	9·80	36·0
Paris	9·46	34·1
Dunsink	9·52	34·8

S.D. −10°, 2857; Magn. 7·6.

		h m s	° ′ ″	
Lalande	1798·2	9 26 24·48	−10 38 9·4	(1)
Munich	1845·3	23·87	7·5	(1)
Brussels	1869·8 and 1867·0	23·49	5·2	(5, 4)
Dunsink	1883·2	23·03	6·2	(4)

Giving the two first places half-weight, we find P.M. = − $0^{s}\cdot0171$ and + $0''\cdot032$, which gives:

	h m s	° ′ ″
Lalande	9 26 23·17	−10 38 7·0
Munich	23·36	6·6
Brussels	23·40	5·0
Dunsink	23·17	6·5

S.D. −10°, 2998; Magn. 8·0.

		h m s	° ′ ″	
Bessel	1824·2	10 2 20·18	−10 30 26·4	(2)
Santini	1857	19·68	20·0	(2)
Munich	1865·3	19·48	19·5	(1)
Gould	1878·2	19·30	20·6	(5)
Dunsink	1883·2	19·20	21·0	(4)

There does not seem to be any motion in declination. Adopting P.M. = − $0^{s}\cdot0172$, the observed Right Ascensions become:

	h m s
Bessel	10 2 19·31
Santini	19·37
Munich	19·31
Gould	19·36
Dunsink	19·34

S.D. −5°, 3071; Magn. 8·0.

		h m s	° ′ ″	
Bessel	1824·2	10 21 60·14	−5 56 59·2	(1)
Munich	1862·3	58·90	57 9·0	(4)
Schjellerup	1863·3	58·72	9·9	(1)
Dunsink	1883·2	58·41	15·1	(4)

Giving Bessel and Schjellerup half-weight, P.M. = − 0ˢ·0296 and − 0″·264, with which the observed places become:

	h	m	s	°	′	″
Bessel	10	21	58·64	−5	57	12·6
Munich			58·52			12·4
Schjellerup			58·37			13·0
Dunsink			58·65			12·9

S.D. −17°, 3488; Magn. 8·2.

		h	m	s	°	′	″	
Lalande	1796·3	11	45	19·51	−17	28	18·7	(1)
Bonn	1853·2			19·57			34·2	(1)
Bonn	1864·3			19·63			35·9	(1)
Dunsink	1882·9			19·76			38·7	(3)

The P.M. in R.A. is somewhat uncertain, and in declination it is just possible that Lalande is merely 15″ in error. However a P.M. = + 0ˢ·0028 and − 0″·231 agrees thus with the observed places:

	h	m	s	°	′	″
Lalande	11	45	19·73	−17	28	36·9
Bonn			19·63			39·2
Bonn			19·66			38·4
Dunsink			19·74			36·9

S.D. −5°, 3444; Magn. 8·0.

		h	m	s	°	′	″	
Lalande	1795·3	12	4	57·17	− 5	13	28·9	(1)
Bessel	1823·3			56·39			28·7	(2)
Munich	1850·8			56·00			34·2	(2)
Bonn	1855·3			55·90			33·2	(2)
Dunsink	1882·7			55·24			37·7	(2)

Giving Lalande half-weight, the P.M. is found = − 0ˢ·0214 and − 0″·112, which gives:

	h	m	s	°	′	″
Lalande	12	4	55·46	− 5	13	37·8
Bessel			55·28			34·5
Munich			55·48			36·9
Bonn			55·58			35·4
Dunsink			55·40			36·8

S.D. −10°, 3457; Magn. 8·6.

		h	m	s	°	′	″	
Lalande	1798·2	12	16	5·87	−10	51	52·0	(1)
Munich	1868·4			6·99			54·2	(2)
Dunsink	1883·0			7·17			58·9	(3)

Assuming P.M. = + 0^{s}·015 and − 0″·10, these places become:

	h	m	s	°	′	″
Lalande	12	16	7·02	−10	51	59·7
Munich			7·09			54·9
Dunsink			7·05			58·1

S.D. −7°, 3409; Magn. 6·3.

		h	m	s	°	′	″	
Lalande	1795·3	12	21	31·62	− 7	58	53·4	(1)
Bessel	1824·3			31·78		59	2·9	(1)
Brisbane	...			...			1·1	(1)
Taylor	1835			31·35			2·9	(2)
Santini	1843			31·09			7·1	
Cape 1850	1852·4			31·00			3·1	(1)
Brussels	1866·8, 1867·5			30·71			5·0	(4, 5)
Armagh	1873·1			30·65			6·8	(5)
Greenwich 9-Year,	1876·4			30·53			4·0	(3)
Gould	1877·5			30·52			5·3	(4)
Dunsink	1882·3			30·50			5·4	(2)

Probably Lalande should be corrected by − 10″, and there is scarcely any indication of P.M. in declination. Giving the five last places double weight, we find the P.M. in R.A. = − 0^{s}·0174, which makes the observed places agree as follows:—

	h	m	s
Lalande	12	21	30·23
Bessel			30·90
Taylor			30·65
Santini			30·53
Cape 1850			30·61
Brussels			30·57
Armagh			30·62
Greenwich			30·55
Gould			30·56
Dunsink			30·63

S.D. −2°, 3528; Magn. 8·5.

		h	m	s	°	′	″	
Lalande	1795·3	12	23	22·22	−2	36	32·2	(1)
Munich	1843·9			20·79			56·0	(2)
Dunsink	1882·8			20·76		37	24·1	(2)

Lalande only observed the transit over one wire, and does not give any fraction of the observed second. In declination there seems to be P.M. equal to about $-0''\cdot66$, which gives:

Lalande	$-2^\circ\ 37'\ 26''\cdot8$
Munich	16·5
Dunsink	19·0

If Lalande should be $10''$ in error, a larger P.M. would make the agreement much better.

S.D. $-8°$, 4352; Magn. 8·8.

		h m s	° ′ ″	
Bessel	1823·4	16 48 51·85	$-\ 8\ 5\ 25\cdot0$	(1)
Dunsink	1886·2	47·86	6 20·2	(1)

Unless there is some error in Bessel's position, this is a very remarkable case of P.M., $= -0^s\cdot063$ and $-0''\cdot88$, or $1''\cdot3$ along a great circle.

S.D. $-22°$, 4475; Magn. 8·5.

		h m s	° ′ ″	
Lalande	1795·5	17 51 26·85	$-22\ 21\ 41''\cdot1$	(1)
Argelander	1850·0	26·14	49·4	(2)
Dunsink	1885·5	25·38	56·6	(1)

Adopting a P.M. $= -0^s\cdot019$ and $-0''\cdot16$, these places become:

	h m s	° ′ ″
Lalande	17 51 25·34	$-22\ 21\ 53''\cdot8$
Argelander	25·66	53·4
Dunsink	25·58	54·9

S.D. $-6°$, 4817; Magn. 8·6.

		h m s	° ′ ″	
Lalande	1796·5	18 31 16·86	$-\ 6\ 53\ 11''\cdot8$	(1)
Bessel	1824·5	16·21	31·8	(1)
Munich	1867·2	16·00	44·1	(2)
Dunsink	1886·1	15·83	52·1	(2)

Giving the last two places double weight, the P.M. is found $= -0^s\cdot0098$ and $-0''\cdot420$, which gives:

	h m s	° ′ ″
Lalande	18 31 16·09	$-\ 6\ 53\ 44''\cdot8$
Bessel	15·72	53·0
Munich	15·92	47·4
Dunsink	15·94	47·5

S.D. −4°, 4617; Magn. 9·0.

		h m s	° ′ ″	
Lalande	1794·6	18 47 47·24	− 4 43 56·8	(1)
Bessel	1824·5	47·17	44 21·7	(1)
Munich	1857·0	47·02	31·7	(3)
Dunsink	1886·6	46·68	47·6	(1)

Giving the Munich place double weight, the P.M. is found = − 0ˢ·0063 and − 0″·521, which gives:

	h m s	° ′ ″
Lalande	18 47 46·73	− 4 44 38·7
Bessel	46·85	48·0
Munich	46·91	41·1
Dunsink	46·75	41·6

S.D. −6°, 5360, Magn. 8·5.

		h m s	° ′ ″	
Lalande	1794·5	19 58 39·22	− 6 56 8·9	(1)
Taylor	1835	39·25	15·6	(2, 3)
Munich	1854·0	39·14	18·2	(4)
Schjellerup	1862·6	38·85	17·2	(1)
Gould	1880·7	38·76	19·0	(3)
Dunsink	1884·6, 85·6	38·76	18·2	(1, 1)

Giving Munich and Gould double weight the P.M. is found = − 0ˢ·0076 and − 0″·094, which, applied to the observations, gives:

	h m s	° ′ ″
Lalande	19 58 38·61	− 6 56 16·5
Taylor	38·87	19·4
Munich	38·98	20·2
Schjellerup	38·76	18·4
Gould	38·80	18·5
Dunsink	38·83	17·2

S.D. −8°, 5318, Magn. 8·7.

		h m s	° ′ ″	
Lalande	1794·6	20 13 1·01	− 8 49 52·0	(1)
Munich	1846·6	1·04	50 12·5	(1)
Dunsink	1881·7	1·01	16·3	(2)

In Right Ascension there is evidently not any P.M., and in Declination the agreement cannot be made very good. P.M. = − 0″·23 gives:

	° ′ ″
Lalande	− 8 50 10·5
Munich	19·0
Dunsink	13·8

S.D. – 21°, 6035, Magn. 8·4.

		h	m	s		°	′	″	
Lalande	1795·6	21	25	23·56	–	21	30	6·9	(1)
Munich	1847·8			22·63				6·8	(1)
Argelander	1849·6			22·50				9·0	(1)
Dunsink	1884·2			21·91				15·4	(2)
Cincinnati	1885·7			21·85				11·5	(4)

The last two places were given double weight. P.M. = – 0ˢ·0196 and – 0″·078 gives :

	h	m	s	°	′	″
Lalande	21	25	22·00	– 21	30	13·1
Munich			22·10			8·9
Argelander			22·00			11·0
Dunsink			22·09			14·7
Cincinnati...			22·06			10·7

S.D. – 16°, 6046, Magn. 6·5.

		h	m	s		°	′	″	
Lalande	1795·7	22	7	51·80	–	16	25	0·0	(2)
Argelander	1849·6			51·70				17·8	(1)
Rümker (Kam.)	1855?			52·07				26·0	(1)
Gould	1877·8			51·98				32 0	(4)
Dunsink	1881·8			52·17				37·5	(1)

These places give a P.M. = + 0ˢ·0028 and – 0″·414, which, applied to the observations, gives :

	h	m	s	°	′	″
Lalande	22	7	52 02	– 16	25	32·8
Argelander			51·77			28·3
Rümker			52·13			34·3
Gould			51·97			30·8
Dunsink			52·15			34·7

S.D. – 18°, 6140, Magn. 7·8.

		h	m	s		°	′	″	
Lalande	1795·7	22	26	19·27	–	18	8	27·5	(2)
Piazzi	1800 ±			19·07				30·5	(3)
Taylor	1835			19·05				31·9	(3, 3)
Argelander	1849·8			18·32				30·2	(2)
Gould	1879·7			18·09				33·8	(3)
Dunsink	1882·4			18·19				35·6	(3)

The Proper Motion is = − 0ˢ·0133 and − 0″·065, which gives:

	h	m	s	°	′	″
Lalande	22	26	18·22	−18	8	32·7
Piazzi			18·07			35·4
Taylor			18·52			34·5
Argelander			17·98			31·8
Gould			18·15			33·5
Dunsink			18·29			35·1

S.D. − 10°, 6008, Magn. 6·8.

		h	m	s	°	′	″	
Lalande	1798·3	22	46	9·69	−10	43	20·6	(2)
Bessel	1823·7			10·43			25·4	(1)
Santini	1843			10·28			20·9	(1)
Munich	1845·4			10·56			20·1	(2)
Geneva	1847·6			10·50			23·1	(5)
Rümker	1849·8			10·50			20·9	(1)
Santini	1857·0			10·46			19·7	(3)
Berlin (Kam.)	1862·7			10·89			20·6	(1)
Armagh	1873·7			10·81			19·9	(2)
Gould	1878·8			10·99			21·6	(4)
Dunsink	1882·7			11·02			20·1	(3)

The late Professor C. H. F. Peters pointed out in the *Astr. Nachr.*, No. 2247, that this star had probably P.M. in Right Ascension. The above more complete collection of positions shows that this is indeed the case, the amount being + 0ˢ·0159, which gives:

	h	m	s
Lalande	22	46	10·91
Bessel			11·25
Santini			10·79
Munich			11·03
Geneva			10·94
Rümker			10·90
Santini			10·75
Berlin			11·09
Armagh			11·02
Gould			10·93
Dunsink			10·90

On the Orbit of the Periodic Comet 1867 I.

By Ludwig Becker, Ph.D.

(*Communicated by Professor R. Copeland*).

I.

This faint comet was discovered by M. Stephan at Marseilles on January 22, 1867, and a week later independently by W. Tempel. At first it appeared like a pretty bright round nebula with a well-defined nucleus, which by its eccentric position suggested the existence of a fan-shaped tail. Its intensity increased a little up to the first week of February, at which time the nucleus was elongated and the nebulous mass surrounding it was about 1″·5 in diameter, but somewhat extended in position-angle 75°. By the end of February the diameter had increased to 2′, and the intensity of the nucleus had gone down to that of a star of the 12th magnitude. The comet was last observed on April 4, when the 15-inch refractor of the Harvard College Observatory showed it as a very faint object.

There are 63 observations, which, extending over 69 days, cover a heliocentric arc of 41°·6, viz. from $v=3°·3$ to 44°·9. 39 of them belong to the first 17 days. I am much indebted to M. Stephan for having forwarded a fine series of observations hitherto unpublished, which have extended the time of observation by 10 days.

At the time of the comet's visibility parabolic elements were published in the *Astronomische Nachrichten* by Messrs. Valentiner, Oppolzer, and Vogel, while Mr. Searle derived elliptic elements with a period of 33·62 years from three observations which embrace almost the whole heliocentric arc.

II.

Although Mr. Searle's elements represent the observations very well, I preferred to base these computations on elements which I had computed some years ago at the suggestion of my esteemed teacher, the late Professor Schönfeld, of Bonn, from all the observations, except those made at Marseilles. This was before the comparison stars had been redetermined. These elements are—

Elements I.

T = 1867, January, 20·51309, Berlin M.T.

$\omega = 357° 42′ 49″·9$
$\Omega = 78\ 19\ 40·6$ } Mean Equinox 1867·0.
$i = 18\ 12\ 59·8$

$\log q = 0·1991244.$
$\log e = 9·9451467.$
Period = 48·7 years.

They give the following ephemeris for Berlin Midnight, the places being corrected for precession and nutation, but not for aberration :—

Berlin, Midnight. 1867.	R.A. h m s	Decl. ° ′ ″	Log Δ.
Jan. 24	2 32 4·59	+15 9 13·8	0·0574
25	34 8·60	15 37 28·5	·0600
26	36 14·43	16 5 31·7	·0625
27	38 22·06	16 33 23·0	·0651
28	40 31·46	17 1 1·8	·0678
29	42 42·64	17 28 27·7	·0704
30	44 55 59	17 55 40·3	·0731
31	47 10·28	18 22 39·1	·0758
Feb. 1	49 26·69	18 49 23·8	·0785
2	51 44·80	19 15 53·9	·0812
3	54 4·61	19 42 9·0	·0839
4	56 26·10	20 8 8·8	·0867
5	2 58 49·23	20 33 52·8	·0895
6	3 1 14·00	20 59 20·7	·0923
7	3 40·38	21 24 32·0	·0951
8	6 8·35	21 49 26·5	·0980
9	8 37·87	22 14 3·7	·1008
10	11 8·93	22 38 23·3	·1037
11	3 13 41·52	+23 2 25·0	0·1066
Feb. 18	3 32 9·79	+25 41 47·3	0·1272
19	34 53·55	26 3 14·1	·1302
20	37 38·58	26 24 20·3	·1332
21	40 24·87	26 45 5·7	·1362
22	43 12·41	27 5 30·0	·1392
23	46 1·15	27 25 32·9	·1422
24	48 51·08	27 45 14·4	·1453
25	51 42·16	28 4 34·1	·1484
26	54 34·37	28 23 32·0	·1514
27	3 57 27·69	28 42 7·9	·1545
28	4 0 22·10	29 0 21·5	·1576
Mar. 1	3 17·56	29 18 12 9	·1607
2	6 14·04	29 35 41·9	·1638
3	9 11·51	29 52 48·2	·1669
4	12 9·95	30 9 31·9	·1700
5	15 9·33	30 25 52·9	·1732

Berlin, Midnight. 1867.	R.A. h m s	Decl. ° ′ ″	Log Δ.
Mar. 6	4 18 9·59	+30 41 51·1	0·1763
7	21 10·72	30 57 26·3	·1794
8	24 12·67	31 12 38·5	·1826
9	4 27 15·42	+31 27 27·7	0·1857
Mar. 25	5 17 15·17	+34 32 16·1	0·2364
26	20 25·47	34 40 34·9	·2396
27	23 35·89	34 48 31·4	·2427
28	26 46·40	34 56 5·9	·2459
29	29 56·95	35 3 18·4	·2491
30	33 7·52	35 10 9·1	·2522
31	36 18·07	35 16 38·0	·2554
Apr. 1	39 28·58	35 22 45·5	·2585
2	42 39·00	35 28 31·7	·2617
3	45 49·30	35 33 56·8	·2648
4	5 48 59·43	+35 39 1·2	0·2680

III.

The comparison stars were reduced from the catalogues to 1867·0 by employing Struve's constants of precession. Those observed by Lalande and Bessel were derived from the original zone-observations. All the positions refer to the system of the *Fundamental-Catalog der Astronomischen Gesellschaft.* For the Second Armagh, the Glasgow, Greenwich 7-year, 1864, and Yarnall catalogues I employed the published reduction tables. The meridian observations, which are based on *Der vorläufige Catalog der Astronomischen Gesellschaft*, are corrected by the table given on pp. 10, 11 in *Publication XIV der Astr. Gesellschaft*, under the heading "Pulkowa, 1845." For reducing the positions of the new Paris catalogues to the system of the *A.G.C.*, 62 stars of the third Paris catalogue were compared with the Glasgow catalogue and a table prepared for the path of the comet only. This table was then combined with the reduction table belonging to the Glasgow catalogue. The positions of the second Paris catalogue were first brought to the system of the third. The table employed had been obtained from 350 comparisons of the positions of telescopic stars which lie near the apparent path of the comet. The same method was applied to Paris I. In order to utilise the reduction tables published by Argelander, I reduced all the positions of the stars, which occur in the *Tabulæ Reductionum*, from the *A.G.C.* to the epoch 1860·0. In so doing *α Geminorum*, *α Canis minoris*, and *α Canis majoris* were excluded. Treating the differences between

the two catalogues in the manner introduced by Professor Auwers, I find the following tables:—

A.G.C.—Tab. Red., 1860.

Decl.	$\Delta\alpha_\delta$.	$\Delta\delta_\delta$.	R.A.	$\Delta\alpha_\alpha$.	$\Delta\delta_\alpha$.
°	s	"	h	s	"
−30	+0·025	−1·25	0	+0·006	−0·07
−25	+0·014	−1·14	1	+0·003	+0·02
−20	+0·004	−1·03	2	−0·004	+0·10
−15	−0·005	−0·92	3	−0·013	+0·17
−10	−0·010	−0·81	4	−0·018	+0·22
− 5	−0·014	−0·70	5	−0·020	+0·25
0	−0·016	−0·62	6	−0·021	+0·26
+ 5	−0·017	−0·59	7	−0·018	+0·24
+10	−0·018	−0·63	8	−0·013	+0·19
+15	−0·018	−0·74	9	−0·007	+0·11
+20	−0·017	−0·78	10	−0·002	+0·02
+25	−0·016	−0·74	11	+0·001	−0·07
+30	−0·013	−0·68	12	+0·003	−0·17
+35	−0·009	−0·58	13	+0·004	−0·24
+40	−0·005	−0·44	14	+0·004	−0·30
+45	0·000	−0·26	15	+0·005	−0·34
+50	+0·006	−0·03	16	+0·005	−0·37
+55	+0·013	+0·25	17	+0·006	−0·38
+60	+0·020	+0·58	18	+0·006	−0·38
+65	+0·029	+0·97	19	+0·007	−0·37
+70	+0·039	+1·40	20	+0·007	−0·33
+75	+0·048	+1·82	21	+0·008	−0·28
			22	+0·009	−0·22
			23	+0·008	−0·15

The sums of the residuals left by these values in the differences of the two catalogues with regard to the signs are $-0^s{\cdot}103$ and $-0''{\cdot}09$ respectively. The average errors amount to $0^s{\cdot}022$ and $0''{\cdot}23$. Three residuals in R.A. are larger than $0^s{\cdot}05$ (belonging to declinations greater than 50°), and six in Decl. exceed $0''{\cdot}5$. The maximum residuals are $0^s{\cdot}085$ and $0''{\cdot}75$ respectively.

All the comparison stars I have reobserved with the 8·6-inch Transit-Circle of Lord Crawford's observatory at Dun Echt.

In taking the mean values of the several determinations of the stars, all the Transit-Circle positions received equal weights, unless they rested on a single observation. The same weight was, however, given to the Leyden zone-stars, even though but

once observed. The positions derived from the *Histoire céleste* were excluded, as were also the declinations of three Bessel zone-stars, Nos. 40, 41, 45. All the other Bessel zone-stars received half-weight. For stars Nos. 4 and 34 the more recent observations alone were taken into account, in order to bring the epoch of the mean position as near as possible to 1867.

List of Comparison Stars.

Mean Equinox, 1867·0.

No.	Mg.	R.A. h m s	Decl. ° ′ ″	
1	8·8	2 36 27·84	+15 32 22·4	AN 2007, 2047, DE.
2	7·8	2 38 19·57	+16 27 27·3	[HC] Par II, III, AN 2047, 2090, DE.
3	12	2 40 10·51	+17 26 6·7	DE.
4	5·7	2 41 52·48	+16 54 32·8	Br, HC, Pi, PM, Arm I, R I, II, Par I, II, III, RC I, II, Y, Gl, DE.
5	9·5	2 45 17·28	+17 48 14·0	DE.
6	9·4	2 47 50·95	+18 19 53·4	DE.
7	9·3	2 49 53·17	+18 41 8·9	R, Par III, DE.
8	9·0	2 51 53·91	+19 32 0·2	DE.
9	12	2 52 9·61	+19 8 22·9	DE.
10	9·1	2 55 7·23	+20 25 37·2	BZ, AN 1768, 1794, DE.
11	8·3	2 55 34·98	+19 48 39·6	AN 1794, Kü, DE.
12	8·8	2 56 14·77	+19 35 21·7	R, AN 1768, DE.
13	7·7	2 56 37·57	+20 57 2·3	[HC] BZ, Par II, III, Arm II, DE.
14	7·5	2 57 53·67	+20 23 0·0	[HC] BZ, R II, AN 1637, 1765, Par III, DE.
15	8·5	2 59 2·11	+20 7 25·4	PM, AN 1765, 1768, DE.
16	12	2 59 24·01	+20 30 50·4	DE.
17	7·7	3 2 27·00	+21 14 16·8	[HC] BZ, Par II, III, AN 1925, Arm, DE.
18	7·8	3 2 36·01	+20 45 47·7	BZ, DE.
19	7·7	3 3 0·32	+21 23 15·8	[HC] BZ, Par I, II, R II, DE.
20	8·8	3 5 5·42	+21 24 38·8	DE.
21	8·0	3 6 8·66	+21 45 12·1	BZ, DE.
22	9·5	3 6 42·15	+22 12 57·0	DE.
23	8·3	3 8 31·47	+22 16 2·9	AN 1632, DE.
24	7·3	3 9 12·19	+22 38 10·7	[HC] BZ, Par I, II, III, DE.
25	9·0	3 12 16·21	+22 57 21·9	BZ, DE.
26	7·4	3 35 46·09	+25 57 21·3	[HC] Par II, AN 1765, 1925, DE.
27	9·0	3 42 43·35	+26 40 14·6	BZ, Y, DE.
28	8·6	3 44 51·34	+27 7 24·3	DE.

No.	Mg.	R.A. h m s	Decl. ° ′ ″	
29	8·5	3 45 11·73	+27 37 58·6	BZ, DE.
30	6·7	3 53 14·40	+28 7 31·7	BZ, R II, DE.
31	7·5	3 54 4·86	+27 45 4·0	[HC] BZ, PM, Par II, DE.
32	8·3	3 54 47·65	+28 4 58·0	BZ, DE.
33	7·8	3 55 26·84	+28 17 25·7	[HC] R II, DE.
34	5·4	3 58 47·39	+28 38 19·9	Br, HC, Pi, R, Arm, Par I, II, Y, 7yrC, DE.
35	7·0	4 6 50·07	+29 34 8·9	BZ, Par II, DE.
36	9·2	4 10 46·03	+30 8 0·6	[AN 1663], DE.
37	8·9	4 22 55·78	+30 59 16·9	BZ, LnZ, DE.
38	8·2	4 24 12·74	+31 7 1·9	[HC] BZ, Par II, DE.
39	9·5	5 20 33·56	+34 41 33·1	AN 1639, DE.
40	8·6	5 26 43·16	+34 57 58·3	BZ, DE.
41	7·9	5 30 0·03	+34 59 43·9	BZ, LnZ, DE.
42	8·9	5 33 45·84	+35 6 58·5	BZ, DE.
43	8·5	5 33 57·02	+35 18 36·2	[HC] DE.
44	12	5 42 48·37	+35 29 51·7	DE.
45	7·3	5 47 59·43	+35 33 19·4	BZ, DE.

It may be mentioned that in addition to the abbreviations in general use Kü designates Küstner's Catalogue of 670 stars, LnZ Leiden Zone-stars, and DE my own Dun Echt observations.

IV.

The observations of the comet are published in *Astr. Nachr.*, Nos. 1627, 1630, 1631, 1632, 1639, 1663, 1764, 1768, in the Annals of Harvard College Observatory and in those of the Vienna Observatory. The reductions to the apparent places and the parallaxes have been computed afresh. For the Berlin observation of February 9 a wrong comparison star has been given, the one used being No. 23 of the preceding list. The unpublished observations already mentioned as having been communicated by M. Stephan are as follows :—

Instr.: Jan. 25, Chercheur de comètes, 182mm. Jan. 27–Feb. 11, Télescope Foucault, 0·80m.

1867	Marseilles M.T. h m s	No. of ✱	Red. to App. Place s	Red. to App. Place ″	Δ R.A. m s	No. of Comp.	Δ Decl. ′ ″	No. of Comp.	App. R.A. h m s	Parall. s	App. Decl. ° ′ ″	Parall. ″
Jan. 25	8 38 45	1	+0·51	−4·1	−2 35·71	10	+1 16·0	10	2 33 52·64	+0·23	+15 33 34·3	+3·9
25	9 38 6	1	+0·51	−4·1	−2 30·26	3	+2 28·1	3	2 33 58·09	+0·30	+15 34 46·4	+4·1
27	7 4 36	2	+0·50	−4·0	−0 22·91	9	+0 23·2	9	2 37 57·16	+0·09	+16 27 46·5	+3·5
27	7 52 46	2	+0·50	−4·0	−0 18·43	4	+1 21·6	4	2 38 1·64	+0·17	+16 28 44·9	+3·6
28	6 24 56	4	+0·51	−4·0	−1 50·21	10	+0 18·6	10	2 40 2·78	+0·03	+16 54 47·4	+3·4
29	6 57 33	3	+0·49	−3·8	+2 5·72	5	−3 5·4	5	2 42 16·72	+0·08	+17 22 57·5	+3·3
30	6 48 0	5	+0·51	−3·9	−0 49·57	10	+1 51·0	10	2 44 28·22	+0·08	+17 50 1·1	+3·2
31	8 16 55	6	+0·51	−3·9	−1 0·67	10	−1 1·9	10	2 46 50·79	+0·21	+18 18 47·6	+3·4
Feb. 1	6 56 32	7	+0·51	−3·9	−0 54·28	10	+2 57·1	10	2 48 59·40	+0·09	+18 44 2·1	+3·1
2	6 55 51	9	+0·51	−3·8	−0 53·03	5	+2 20·2	5	2 51 17·09	+0·09	+19 10 39·3	+3·0
3	6 51 32	8	+0·50	−3·8	+1 42·03	10	+4 53·7	10	2 53 36·44	+0·08	+19 36 50·1	+3·0
5	7 9 39	16	+0·52	−3·8	−1 2·61	6	−1 40·0	6	2 58 21·92	+0·12	+20 29 6·6	+2·9
7	7 41 51	20	+0·54	−3·7	−1 50·16	5	−4 6·3	5	3 3 15·80	+0·17	+21 20 28·8	+2·8
8	8 39 58	21	+0·52	−3·7	−0 19·63	10	+1 12·1	10	3 5 49·55	+0·25	+21 46 20·5	+3·1
9	7 18 3	22	+0·51	−3·6	+1 27·76	6	−3 15·4	6	3 8 10·42	+0·14	+22 9 38·0	+2·7
10	9 5 58	24	+0·51	−3·6	+1 39·63	5	−2 11·4	5	3 10 52·33	+0·28	+22 35 55·7	+3·1
11	7 56 5	25	+0·51	−3·7	+1 1·09	5	+1 28·8	5	3 13 17·81	+0·19	+22 58 47·0	+2·7

Janvier 25.—La comète a la forme d'une nébulosité ronde, avec un noyau un peu excentrique.

Janvier 26.—La comète a l'aspect d'une nébulosité arrondie, avec un noyau brillant. On distingue assez difficilement une apparence de queue en éventail.

Janvier 27.—La comète a sensiblement le même aspect que le jour précédent.

Janvier 28.—La comète paraît un peu plus faible que le 26, mais le ciel est moins pur.

Janvier 29.—L'apparence de la comète est sensiblement la même que la veille.

Janvier 31.—L'éclat de la comète est un peu moindre que la veille, la queue est dirigée vers l'E. S.E.

Février 1.—L'éclat et l'étendue de la comète ont augmenté en apparence depuis la veille (très beau ciel). Le noyau est plus allongé et plus brillant. La queue, toujours vague, s'étend vers l'E.$\frac{1}{4}$N.E.

Février 5.—La comète est assez belle. Elle semble ne pas avoir augmenté en étendue, mais un peu en éclat.

The Elements I. leave the residuals (O − C) as given in the third and fourth columns of the following table; the fifth and sixth columns show the residuals left by the final elements:—

	Berlin M.T.—aber^{a}.	Elements I. $\Delta\alpha\cos\delta$	Elements I. $\Delta\delta$	Elements III. $\Delta\alpha\cos\delta$	Elements III. $\Delta\delta$
		″	″	″	″
Marseilles	Jan. 25·37593	− 3·6	−20·8	+ 3·1	− 4·0
„	25·41714	+ 1·9	−18·1	+ 8·6	− 1·4
„	27·31047	− 6·9	−17·2	− 2·2	− 4·4
„	27·34392	− 3·0	−14·5	+ 1·7	− 1·7
„	28·28288	− 5·7	−11·9	− 2·0	− 0·4
„	29·30550	− 2·7	− 7·8	+ 0·1	+ 2·1
Marseilles	Jan. 30·29882	− 5·7	− 8·7	− 3·9	− 0·7
„	31·36052	− 5·6	− 3·1	− 4·9	+ 3·4
„	Feb. 1·30466	− 6·0	− 6·3	− 6·1	− 0·9
„	2·30414	− 6·2	− 1·4	− 6·9	+ 3·0
„	3·30110	− 2·3	− 3·7	− 3·5	0·0
Königsberg	Feb. 4·27786	+ 7·5	− 1·0	+10·7	+ 7·6
„	4·27786	+17·6	+10·9		
Berlin	4·34003	− 4·5	+ 1·7	− 6·3	+ 4·3
Königsberg	4·37520	+15·8	+ 0·2	+14·0	+ 2·8
Vienna	4·39010	−13·4	−17·0	+ 4·6	+ 6·8
„	4·39010	+26·5	+25·4		

	Berlin M.T.—aber^{n}.	Elements I. $\Delta\alpha \cos\delta$	Elements I. $\Delta\delta$	Elements III. $\Delta\alpha \cos\delta$	Elements III. $\Delta\delta$
		″	″	″	″
Leipzig	Feb. 4·43158	+11·3	−10·1	+ 9·4	− 7·5
Berlin	4·44144	− 1·7	− 1·0	− 3·6	+ 1·5
,,	5·29310	− 1·6	−10·7	− 3·8	− 8·8
Leipzig	5·30610	− 0·6	+ 1·0	− 2·8	+ 2·9
Marseilles	5·31360	− 5·5	+ 3·3	− 7·7	+ 5·2
Leipzig	6·29108	− 2·5	+ 1·3	− 4·9	+ 2·4
Durham	6·38425		+13·8		+14·9
,,	6·38692	+19·3		+16·8	
Leipzig	Feb. 7·26669	+ 4·8	+ 1·5	+ 2·0	+ 2·1
Berlin	7·28210	− 2·0	− 9·6	− 4·8	− 9·0
Altona	7·32479	+12·7	+10·0	+ 9·9	+10·5
Marseilles	7·33586	− 3·8	+ 6·5	− 6·6	+ 7·0
Vienna, Josephstadt	7·39926	+13·4	+ 9·5	+10·6	+10·0
Durham	8·36120		−15·1		−15·1
,,	8·36671	+12·3		+ 9·2	
Marseilles	8·37617	− 2·0	+ 1·2	− 5·1	+ 1·2
Vienna, Josephstadt	9·27506	+ 9·5	+ 5·7	+ 6·3	+ 5·3
Leipzig	9·31474	+ 5·7	− 1·4	+ 2·5	− 1·8
Marseilles	9·31924	− 2·4	+ 2·7	− 5·6	+ 2·3
Berlin	9·36226	− 0·1	+ 4·4	− 3·3	+ 4·0
Marseilles	10·39413	− 3·6	+ 9·2	− 6·9	+ 8·4
,,	11·34556	+ 1·9	+ 6·4	− 1·5	+ 5·3
Berlin	Feb. 19·28463	− 3·2	− 4·6	− 6·1	− 6·3
Leipzig	21·30571	+ 9·8	+ 0·7	+ 7·4	− 0·7
Athens	23·31316	+11·9	+13·1	+ 4·6	− 1·7
,,	23·32221	+ 0·8	−14·5		
,,	25·26825	+ 4·6	+18·9	− 2·1	+ 0·3
,,	25·28658	− 6·5	−17·3		
,,	26·30190	+ 1·2	−19·2		
,,	26·30917	+ 4·4	−17·8	+ 1·9	−11·5
,,	26·31813	+ 2·8	+ 3·4		
,,	27·26480	− 0·7	− 6·9	− 1·2	− 6·8
Athens	Feb. 28·30663	+ 1·7	− 3·5	+ 1·5	− 3·2
Leipzig	Mar. 2·32205	− 7·0	− 5·7	− 6·3	− 4·8
Cambridge, Mass.	2·69259	+ 3·1	+ 4·7	+ 4·1	+ 5·8
Vienna	4·34355	− 4·5	+ 1·3	− 2·6	+ 2·9
Athens	8·27622	+11·9	− 8·2	+11·5	+ 0·7
,,	8·28552	+ 4·5	+ 4·3		

	Berlin M.T.—aber^{n}.	Elements I. $\Delta\alpha \cos\delta$	Elements I. $\Delta\delta$	Elements III. $\Delta\alpha \cos\delta$	Elements III. $\Delta\delta$
Cambridge, Mass.	Mar. 26·57464	−12″·8	− 2″·4	− 7″·9	+ 4″·7
,,	28·58127	−12·4	−18·2	− 8·7	−10·9
,,	28·63935	− 8·6	− 7·9	− 4·9	− 0·6
,,	29·58687	+ 6·0	− 9·4	+ 9·3	− 1·9
Cambridge, Mass.	Mar. 30·65261	− 1·3	− 6·8	+ 1·4	+ 0·8
,,	31·63423	+ 7·5	− 3·9	+ 9·6	+ 3·8
,,	Apr. 2·55690	− 3·3	+ 0·7	− 2·4	+ 8·6
,,	3·64152	− 0″·4	− 6·9	− 0·1	+ 1·2

From these residuals I graphically constructed the correction of the ephemeris which enabled me to compute the probable error of one observation at the several observatories. Eight normal places were derived, having regard to the weights of the observations, and the corrections of the Elements I. computed. The result is—

T = Jan. 20·22330 Berlin M.T. ± 0·05780

$\omega = 357^{\circ}\ 30'\ 23''{\cdot}6 \pm 3'\ 41''{\cdot}2$
$\Omega = 78\ 28\ 40{\cdot}3 \pm 2\ \ 8{\cdot}1$ } Mean Equinox 1867·0
$i = 18\ 12\ 24{\cdot}2 \pm \ \ 17{\cdot}3$

$q = 1{\cdot}576578 \pm 0{\cdot}001242$

$a = 11{\cdot}5054 \pm 0{\cdot}3894$

Period = 39·0 years ± 2·0

A glance at the preceding table shows that all the normal places, except the third and fourth, rest almost entirely on observations at one observatory. Besides, as the weight 2 was given to the observations made at Marseilles and to the R.A.'s of the Berlin observations, the fourth normal place and the R.A.'s of the third rest as to three-fourths of their weight on observations of these two observatories. Further, the latter yield the same mean correction of the ephemeris, which is 12″ smaller than the mean of those of the other observations in the third and fourth normal places; therefore, the first four normal places will be influenced by identical systematic errors in the observations of the Marseilles and Berlin observations, and these errors must have an effect on the determination of the orbit—the more so as they obtained a preponderating influence over the last four normal places by the process of weighting. It is worth noting that the residuals left by the last elements in the R.A.'s of the two observatories after January 30 are all negative, the average deviation being 3″·7. Even if only the Marseilles and Berlin observations were taken into account in the first four normal places, they could not be better

represented without introducing unreasonable errors in the other normal places and in the declinations of the Marseilles observations. In order to obviate the influence of systematic errors as much as the unfavourable arrangement of the observations allows, I decided to repeat the determination of the orbit, on the assumption that all the observations are equally accurate, and also that the normal places have the same weight. The details of this computation will be found in the following pages:—

V.

The normal places, as derived from the data give above, are—

Berlin M.T. 1867.	R.A. 1867·0.	Decl. 1867·0.
Jan. 27·0	39° 19′ 21″·2	+16° 19′ 18″·3
Feb. 1·5	42 21 28·1	+18 49 24·5
5·0	44 24 19·2	+20 21 8·7
9·0	46 50 39·6	+22 1 54·9
23·5	56 30 9·7	+27 25 35·1
Mar. 4·0	62 39 58·6	+30 1 18·3
28·5	81 41 15·8	+34 56 4·6
Apr. 1·5	84 51 56·6	+35 22 49·5

I founded the investigation on the following elements:—

Elements II.

T = Jan. 20·29970 Berlin M.T.

$\omega = 357° 33′ 36″·9$
$\Omega = 78\ 25\ 42·7$ } Mean Equinox 1867·0.
$i = 18\ 12\ 43·1$

$\log q = 0·1981805$.

$\log e = 9·9390823$.

The perturbations produced by the action of *Venus*, the Earth, *Mars*, and *Jupiter* were computed at intervals of twenty days, according to Encke's method. They refer to the Equator, and are given in units of the seventh decimal:—

	ξ	η	ζ
Jan. 12·0	− 1·5	− 0·5	−0·2
17·0	− 0·3	− 0·1	−0·1
22·0	0·0	0·0	0·0
27·0	− 0·4	− 0·1	0·0
Feb. 1·0	− 1·3	− 0·3	−0·1
6·0	− 2·8	− 0·5	−0·3
11·0	− 5·0	− 0·7	−0·4
16·0	− 7·7	− 0·7	−0·5
21·0	−10·9	− 0·4	−0·6
26·0	−14·6	+ 0·2	−0·6

	ξ	η	ζ
Mar. 3·0	−18·8	+ 1·2	−0·5
8·0	−23·5	+ 2·8	−0·3
13·0	−28·8	+ 5·0	+0·2
18·0	−34·6	+ 7·9	+0·9
23·0	−40·9	+11·6	+1·9
28·0	−47·9	+16·1	+3·2
Apr. 2·0	−55·6	+21·6	+4·8
7·0	−64·0	+28·1	+6·7
12·0	−73·3	+35·7	+9·1

The polar co-ordinates of the Sun were taken from Le Verrier's Solar Tables in vol. iv. of the *Annales de l'Observatoire de Paris*. The rectangular equatorial co-ordinates contain the foregoing perturbations.

Mean Equinox 1867·0.

Berlin M.T.	☉	B	R
Jan. 27·0	307° 6′ 24″·69	+0″·30	0·9849122
Feb. 1·5	312 41 27·52	+0·51	0·9857133
5·0	316 14 25·27	+0·28	0·9862771
9·0	320 17 28·95	−0·20	0·9869651
23·5	334 54 53·31	+0·38	0·9899779
Mar. 4·0	343 26 41·43	+0·35	0·9921111
28·5	7 48 41·43	+0·57	0·9988647
Apr. 1·5	11 45 31·10	+0·23	1·0000407

	X+ξ	Y+η	Z+ζ
Jan. 27·0	+0·5942010	−0·7205691	−0·3126618
Feb. 1·5	+0·6683568	−0·6646485	−0·2883961
5·0	+0·7123359	−0·6257729	−0·2715289
9·0	+0·7592753	−0·5784476	−0·2509963
23·5	+0·8966005	−0·3850325	−0·1670682
Mar. 4·0	+0·9509819	−0·2593300	−0·1125245
28·5	+0·9895910	+0·1245419	+0·0540428
Apr. 1·5	+0·9790490	+0·1869579	+0·0811240

For computing the coefficients of the equations I employed the formulæ published by Schönfeld in *Astr. Nachr.*, Nos. 2693–95. Schönfeld introduces the variables $d\mathrm{T}$, $d\frac{1}{a}$, dq, and instead of the corrections of ω, Ω, i, $d\kappa = d\omega + \cos i\, d\,\Omega$, $d\lambda = \sin\omega\, di - \cos\omega \sin i\, d\,\Omega$, $d\nu = \cos\omega\, di + \sin\omega \sin i\, d\,\Omega$. But since the differential quotients with reference to κ and T

turned out to be very nearly proportional to each other, I replaced κ by another variable, ι, defined by—

$$d\iota = d\kappa - \frac{k\sqrt{1+e}}{q^{\frac{3}{2}}}\,d\mathrm{T}.$$

The differential quotients are then expressed by—

$$\cos\delta\,\frac{d\alpha}{d\iota} = \cos\delta\,\frac{d\alpha}{d\kappa};\quad \frac{d\delta}{d\iota} = \frac{d\delta}{d\kappa}$$

$$\cos\delta\left(\frac{d\alpha}{d\,\mathrm{T}}\right) = \cos\delta\,\frac{d\alpha}{d\,\mathrm{T}} + \frac{k\sqrt{1+e}}{q^{\frac{3}{2}}}\cos\delta\,\frac{d\alpha}{d\kappa}$$

$$\left(\frac{d\delta}{d\,\mathrm{T}}\right) = \frac{d\delta}{d\,\mathrm{T}} + \frac{k\sqrt{1+e}}{q^{\frac{3}{2}}}\,\frac{d\delta}{d\kappa}.$$

These quantities may be computed by Schönfeld's formulæ (48) and (49), or from—

$$c\cos\mathrm{C} = \frac{r}{p}(1+e)^2 - \frac{p}{r};\quad c\sin\mathrm{C} = e\sin v$$

$$\cos\delta\left(\frac{d\alpha}{d\,\mathrm{T}}\right) = \frac{\sin\gamma}{\Delta}\,\frac{k}{\sqrt{p}}\,c\cos(g+v+\mathrm{C});$$

$$\left(\frac{d\delta}{d\,\mathrm{T}}\right) = \frac{\sin\gamma}{\Delta}\,\frac{k}{\sqrt{p}}\,c\cos(g'+v+\mathrm{C})$$

in which the notation is the same as in the essay referred to. The numerical values of the coefficients are as follows:—

Right Ascension.

No. of Norm. place.	$d\iota$	$d\,\mathrm{T}$	$d\frac{1}{a}$	dq	$d\lambda$	$d\nu$	log n
1	9·91996	1·82541n	3·79025n	4·96400	9·86027n	8·76097n	0·6156
2	9·90659	2·03883n	4·05739n	4·89382	9·84156n	9·00369n	0·3740n
3	9·89949	2·11468n	4·17042n	4·84217	9·82803n	9·10077n	0·7279
4	9·89277	2·17121n	4·27206n	4·77444	9·81097n	9·18382n	0·5234
5	9·87963	2·21094n	4·51355n	4·37006	9·73344n	9·35446n	0·3284
6	9·87863	2·13190n	4·60351n	3·48039	9·67527n	9·39999n	0·3998
7	9·88941	1·76044	4·74646n	4·68903n	9·44371n	9·39634n	0·2359n
8	9·89158	2·00171	4·75755n	4·74768n	9·39518n	9·37949n	0·5548

Declination.

1	9·86461	1·26014n	3·71464n	4·34788	0·05075	8·95145	0·5441n
2	9·85446	1·35034n	3·96824n	4·01987	0·03411	9·19624	9·9031
3	9·84690	1·30735n	4·07038n	3·52028	0·02318	9·29592	0·4624
4	9·83723	1·14290n	4·15753n	3·64627n	0·01047	9·38332	0·3617
5	9·79169	1·57000	4·32901n	4·44038n	9·96287	9·58389	0·6902n
6	9·75631	1·89467	4·36545n	4·56638n	9·93386	9·65858	9·6990n
7	9·60825	2·25674	4·29596n	4·65180n	9·84192	9·79455	0·6435n
8	9·57594	2·27743	4·26202n	4·64189n	9·82505	9·80936	0·0000

The coefficients of the equations are given in logarithms. They contain already the factors which allow the elementary corrections to be obtained in their respective units. n denotes the difference (O−C) between the normal places and the positions, computed from the Elements II., multiplied in R.A. by cos δ.

I introduce—

$$x = (9{\cdot}91996)\ di$$
$$y = (2{\cdot}27743)\ d\mathrm{T}$$
$$z = (4{\cdot}75755)\ d\frac{\mathrm{I}}{a}$$
$$u = (4{\cdot}96400)\ dq$$
$$v = 0{\cdot}05075\ d\lambda$$
$$w = 9{\cdot}80936\ dv\ ;$$

Unit of error $= (0{\cdot}7279)\ ;$

and obtain by the Method of Least Squares the normal equations :—

$$+7{\cdot}6314v\ +4{\cdot}1393w\ +3{\cdot}2527y\ +\ 1{\cdot}3424x\ -2{\cdot}6594u\ -0{\cdot}1189z\ = -2{\cdot}4689$$
$$+4{\cdot}1393v\ +3{\cdot}7897w\ +2{\cdot}9356y\ +\ 0{\cdot}7203x\ -1{\cdot}5489u\ +0{\cdot}0193z\ = -1{\cdot}7382$$
$$+3{\cdot}2527v\ +2{\cdot}9356w\ +5{\cdot}3242y\ -\ 1{\cdot}9459x\ -3{\cdot}7981u\ -0{\cdot}0700z\ = -2{\cdot}4749$$
$$+1{\cdot}3424v\ +0{\cdot}7203w\ -1{\cdot}9459y\ +11{\cdot}5159x\ +1{\cdot}7011u\ -5{\cdot}3272z\ = +2{\cdot}3051$$
$$-2{\cdot}6594v\ -1{\cdot}5489w\ -3{\cdot}7981y\ +\ 1{\cdot}7011x\ +4{\cdot}2187u\ +0{\cdot}8315z\ = +1{\cdot}9161$$
$$-0{\cdot}1189v\ +0{\cdot}0193w\ -0{\cdot}0700y\ -\ 5{\cdot}3272x\ +0{\cdot}8315u\ +3{\cdot}6572z\ = -0{\cdot}9521$$

and further—

$$+7{\cdot}6314v\ +4{\cdot}1393w\ +3{\cdot}2527y\ +\ 1{\cdot}3424x\ -2{\cdot}6594u\ -0{\cdot}1189z\ = -2{\cdot}4689$$
$$+1{\cdot}5445w\ +1{\cdot}1713y\ -\ 0{\cdot}0078x\ -0{\cdot}1064u\ +0{\cdot}0838z\ = -0{\cdot}3990$$
$$+3{\cdot}0495y\ -\ 2{\cdot}5122x\ -2{\cdot}5839u\ -0{\cdot}0828z\ = -1{\cdot}1200$$
$$+\ 9{\cdot}2103x\ +0{\cdot}0398u\ -5{\cdot}3741z\ = +1{\cdot}8147$$
$$+1{\cdot}0952u\ +0{\cdot}7479z\ = +0{\cdot}0714$$
$$+0{\cdot}0008z\ = +0{\cdot}0106$$

The variables expressed in functions of z and of $d\frac{\mathrm{I}}{a}$ become—

$$u = +(8{\cdot}8142) - (9{\cdot}83493)\,z \qquad dq = +(4{\cdot}5781) - (9{\cdot}62848)\,d\frac{\mathrm{I}}{a}$$

$$y = -(9{\cdot}1759) - (8{\cdot}8396)\,z \qquad d\mathrm{T} = -(7{\cdot}6263) - (1{\cdot}3197)\ d\frac{\mathrm{I}}{a}$$

$$x = +(9{\cdot}2939) + (9{\cdot}76821)\,z \qquad di = +(0{\cdot}1018) + (4{\cdot}60580)\,d\frac{\mathrm{I}}{a}$$

$$v = -(9{\cdot}2922) - (9{\cdot}43368)\,z \qquad d\lambda = -(9{\cdot}9694) - (4{\cdot}14048)\,d\frac{\mathrm{I}}{a}$$

$$w = -(9{\cdot}1436) - (8{\cdot}6631)\,z \qquad dv = -(0{\cdot}0622) - (3{\cdot}6113)\ d\frac{\mathrm{I}}{a}.$$

These quantities substituted in the original equations give the following equations of the form $A d\frac{I}{a} = N$:—

Right Ascension.

	1	2	3	4
N	+ 1″·70	− 4″·92	+ 2″·75	+ 0″·71
A	−91	+126	+183	+184
	5	6	7	8
N	− 0·37	+ 0·24	− 2·83	+ 2·73
A	−215	−512	−74	+306

Declination.

	1	2	3	4
N	− 3″·44	+ 0″·95	+ 3″·12	+ 2″·62
A	−631	−10	+231	+392
	5	6	7	8
N	− 4·12	+ 0·58	− 2·61	+ 2·85
A	+331	+118	−251	−275

The residuals become a minimum for $\log d\frac{I}{u} = 7{\cdot}3885 - 10$. The corrections to be applied to Elements II. are therefore—

$$dT = -0{\cdot}05531$$
$$d\omega = -2'\ 22''{\cdot}3$$
$$d\Omega = +1\ 52{\cdot}6$$
$$di = -\ \ 9{\cdot}6$$
$$\log dq = 7{\cdot}01543\ n$$
$$\log d\frac{I}{a} = 7{\cdot}3885.$$

They reduce $[nn] = 160''$ to $[nn6] = 104''$, and the mean error of the normal place becomes $\epsilon = \pm 3''{\cdot}2$.

Adding the foregoing corrections to the Elements II., I get the definitive elements, which I give along with their probable errors :—

Elements III.

T = 1867, Jan., 20·24439, Berlin M.T.		± 0·06026 (± 0·01748)
ω = 357° 31′ 14″·6		± 3′ 38″·2 (± 43″·1)
Ω = 78 27 35·3	Mean Equin. 1867·0	± 2 2·2 (± 5·9)
i = 18 12 33·5		± 12·6 (± 5·4)
q = 1·577231		± 0·001175 (± 0·000034)
a = 11·7138		± 0·3790
Period = 40·1 years		± 2·0
log e = 9·9371930		

The figures in brackets show the probable error if a be considered constant.

These elements represent the normal places, thus :—

	Direct Computation.		Computed from the Equations.	
	$\Delta\alpha \cos\delta$	$\Delta\delta$	$\Delta\alpha \cos\delta$	$\Delta\delta$
1867.	"	"	"	"
Jan. 27·0	+2·0	−1·8	+1·9	−1·9
Feb. 1·5	−5·1	+1·0	−5·2	+1·0
5·0	+2·3	+2·6	+2·3	+2·5
9·0	+0·3	+1·7	+0·3	+1·7
23·5	+0·2	−4·9	+0·2	−4·9
Mar. 4·0	+1·6	+0·3	+1·5	+0·3
28·5	−2·5	−2·0	−2·6	−2·0
Apr. 1·5	+2·1	+3·5	+2·0	+3·5

VI.

It will be noticed that the definitive elements agree within the limits given by their probable errors with those derived on the assumption of different weights (§ IV.). This agreement becomes still closer if the elements be reduced to the same period. It remains to be shown how much the period may be varied without doing violence to the observations. The following table contains the residuals left in the normal places by the definitive elements when the period lies between twenty-five and seventy years :—

Right Ascension.

Period in Years.	25	30	35	37	39	40	41	43	45	50	55	70
	″	″	″	″	″	″	″	″	″	″	″	″
1	+ 4·9	+ 3·7	+ 2·7	+ 2·4	+ 2·1	+ 2·0	+ 1·9	+ 1·6	+ 1·4	+ 0·9	+ 0·5	− 0·4
2	− 9·1	− 7·4	− 6·1	− 5·7	− 5·3	− 5·1	− 4·9	− 4·6	− 4·3	− 3·6	− 3·1	− 1·8
3	− 3·5	− 1·0	+ 0·8	+ 1·4	+ 2·0	+ 2·3	+ 2·5	+ 3·0	+ 3·5	+ 4·4	+ 5·3	+ 7·1
4	− 5·5	− 3·0	− 1·2	− 0·6	0·0	+ 0·3	+ 0·5	+ 1·0	+ 1·5	+ 2·5	+ 3·3	+ 5·2
5	+ 7·0	+ 4·1	+ 1·9	+ 1·2	+ 0·5	+ 0·2	− 0·1	− 0·6	− 1·2	− 2·3	− 3·3	− 5·5
6	+ 17·7	+ 10·9	+ 5·7	+ 4·0	+ 2·4	+ 1·7	+ 0·9	− 0·4	− 1·6	− 4·4	− 6·7	− 12·0
7	− 0·2	− 1·2	− 1·9	− 2·1	− 2·4	− 2·5	− 2·6	− 2·8	− 3·0	− 3·4	− 3·7	− 4·5
8	− 7·6	− 3·5	− 0·4	+ 0·7	+ 1·6	+ 2·1	+ 2·5	+ 3·3	+ 4·0	+ 5·7	+ 7·1	+ 10·1
[vv]	569	228	86	63	51	49	48	53	64	108	169	377

Declination.

Period in Years.	25	30	35	37	39	40	41	43	45	50	55	70
1	+ 18·1	+ 9·7	+ 3·3	+ 1·2	− 0·8	− 1·7	− 2·6	− 4·3	− 5·8	− 9·2	− 12·0	− 18·5
2	+ 1·3	+ 1·2	+ 1·1	+ 1·0	+ 1·0	+ 1·0	+ 1·0	+ 1·0	+ 0·9	+ 0·9	+ 0·8	+ 0·7
3	− 4·7	− 1·6	+ 0·7	+ 1·5	+ 2·2	+ 2·6	+ 2·9	+ 3·5	+ 4·1	+ 5·3	+ 6·4	+ 8·7
4	− 10·7	− 5·4	− 1·5	− 0·1	+ 1·1	+ 1·7	+ 2·2	+ 3·2	+ 4·2	+ 6·3	+ 8·1	+ 12·1
5	− 15·3	− 10·9	− 7·6	− 6·5	− 5·4	− 4·9	− 4·5	− 3·6	− 2·8	− 1·0	+ 0·5	+ 3·9
6	− 3·5	− 1·8	− 0·7	− 0·3	+ 0·1	+ 0·3	+ 0·4	+ 0·8	+ 1·0	+ 1·7	+ 2·2	+ 3·4
7	+ 5·9	+ 2·6	0·0	− 0·8	− 1·6	− 2·0	− 2·3	− 3·0	− 3·6	− 4·9	− 6·1	− 8·7
8	+ 12·2	+ 8·5	+ 5·7	+ 4·8	+ 3·0	+ 3·5	+ 3·2	+ 2·4	+ 1·8	+ 0·3	− 1·0	− 3·8
[vv]	896	328	106	71	55	54	57	70	94	181	294	682

In spite of the inferior quality of the observations and the unfavourable arrangement, one may safely assume that the period will not be beyond the limits thirty and fifty-five years, but will lie most probably between thirty-five and forty-five years. This fixes the time of the comet's next appearance between 1902 and 1912.

In the next table are shown the geocentric positions of the comet and its brightness (*I.*) on twelve days of the year for five points of its orbit.

		Jan. 0.	Feb. 1.	Mar. 5.	Apr. 6.	May 8.	June 9.	July 11	Aug. 12.	Sept. 13.	Oct. 15.	Nov. 16.	Dec. 18.
64 days before Perihelion Passage	R.A.	$0^{h}\cdot5$	$0^{h}\cdot8$	$1^{h}\cdot4$	$2^{h}\cdot0$	$2^{h}\cdot7$	$3^{h}\cdot5$	$4^{h}\cdot2$	$4^{h}\cdot7$	$4^{h}\cdot9$	$3^{h}\cdot9$	$1^{h}\cdot7$	$0^{h}\cdot6$
	Decl.	$-11°$	$-6°$	$-1°$	$+4°$	$+8°$	$+10°$	$+11°$	$+10°$	$+6°$	$-5°$	$-16°$	$-14°$
	I.	0·4	0·2	0·2	0·1	0·1	0·2	0·2	0·3	0·6	1·3	1·3	0·6
32 days before Perihelion Passage	R.A.	$1^{h}\cdot4$	$1^{h}\cdot5$	$2^{h}\cdot0$	$3^{h}\cdot3$	$3^{h}\cdot4$	$4^{h}\cdot2$	$5^{h}\cdot0$	$5^{h}\cdot7$	$6^{h}\cdot2$	$6^{h}\cdot1$	$4^{h}\cdot0$	$1^{h}\cdot7$
	Decl.	$-2°$	$+2°$	$+6°$	$+11°$	$+14°$	$+17°$	$+18°$	$+17°$	$+16°$	$+11°$	$+2°$	$-3°$
	I.	0·9	0·4	0·3	0·2	0·2	0·2	0·2	0·3	0·6	1·3	2·9	1·4
Perihelion Passage	R.A.	$2^{h}\cdot9$	$2^{h}\cdot4$	$2^{h}\cdot8$	$3^{h}\cdot4$	$4^{h}\cdot2$	$5^{h}\cdot1$	$5^{h}\cdot9$	$6^{h}\cdot7$	$7^{h}\cdot4$	$7^{h}\cdot8$	$7^{h}\cdot1$	$3^{h}\cdot8$
	Decl.	$+15°$	$+13°$	$+15°$	$+18°$	$+21°$	$+22°$	$+23°$	$+23°$	$+21°$	$+20°$	$+21°$	$+18°$
	I.	2·2	0·8	0·4	0·3	0·2	0·2	0·2	0·3	0·4	0·8	2·4	3·3
32 days after Perihelion Passage	R.A.	$6^{h}\cdot0$	$3^{h}\cdot8$	$3^{h}\cdot8$	$4^{h}\cdot3$	$5^{h}\cdot1$	$6^{h}\cdot0$	$6^{h}\cdot8$	$7^{h}\cdot7$	$8^{h}\cdot5$	$9^{h}\cdot0$	$9^{h}\cdot2$	$7^{h}\cdot6$
	Decl.	$+38°$	$+29°$	$+26°$	$+26°$	$+27°$	$+27°$	$+26°$	$+25°$	$+24°$	$+22°$	$+25°$	$+35°$
	I.	2·9	1·2	0·5	0·3	0·2	0·2	0·2	0·2	0·3	0·4	1·0	2·6
64 days after Perihelion Passage	R.A.	$9^{h}\cdot5$	$6^{h}\cdot4$	$5^{h}\cdot2$	$5^{h}\cdot4$	$5^{h}\cdot9$	$6^{h}\cdot9$	$7^{h}\cdot7$	$8^{h}\cdot5$	$9^{h}\cdot3$	$9^{h}\cdot8$	$10^{h}\cdot4$	$10^{h}\cdot1$
	Decl.	$+38°$	$+45°$	$+37°$	$+33°$	$+32°$	$+30°$	$+28°$	$+26°$	$+24°$	$+22°$	$+23°$	$+32°$
	I.	1·4	1·3	0·6	0·3	0·2	0·2	0·1	0·1	0·2	0·3	0·4	1·0

The brightness at the time of its discovery has been taken as unity. At the time of the last observation the computed intensity was $I=0{\cdot}3$, when it was a difficult object in the 15-inch Refractor of Harvard College Observatory. Its rediscovery may therefore be expected if it passes its perihelion between September and April.

Notes on some Star Photographs recently taken at Sydney Observatory. No. 2. By H. C. Russell, B.A., F.R.S., Government Astronomer.

It will be remembered that in the November number of the *Monthly Notices* I gave an account of the Milky Way about *η Argûs*, and stated that the photograph was *under-exposed.* On several occasions since I have tried longer exposures with the same camera and plates (Ilford Extra Rapid), getting better results as the time of exposure increased.

I have at last got an exposure of eight hours on a fine clear night, and this makes the whole aspect of this part of the Milky Way so different that I send glass and paper positives of it, which should be compared with those sent before to fully realise the enormous difference which the increased exposure and clearer night have made. In comparing the plates it is necessary to remember that the camera slide has been turned 90°, and, therefore, the long way of the plate is now north and south.

I have not attempted as yet a general count of the two photographs, but there is obviously a great number of additional stars, and hence it is not to be wondered at that the whole aspect of the Milky Way about *η Argûs* appears changed, and at the same time it is satisfactory to note that little details, dark spots and lines, visible in the fainter negative are reproduced in this; the nebula itself is much brighter, and the details more defined, the outlying wreaths of nebula extending over a much wider space than has appeared in any drawing or previous photograph. This feature is best seen in the paper print of this object made from the *portrait camera negative* No. 81, which was exposed eight hours. In that photograph the great rift which divides the nebula seems to originate in an oval dark space and passes thence upwards and towards the preceding side, passing first between two well-marked clusters of stars; thence it passes another cluster on the left, and at the third cluster it turns away to the left; it is quite evident also that the nebulous matter here is bounded by this dark rift, and includes the middle cluster on the left, which is an extension in this direction four times as far as Herschel traced it with his reflector at the Cape. Starting again from the rift near the dark oval and going south, the nebula is extended nearly as far again as Herschel saw it, and

the parallel curved wreaths of nebula are much more distinct than in my earlier photographs, but still seem to want longer exposure.

In the dark oval space which lies near the southern extremity of the nebula no increase of exposure suffices to show any nebulous light whatever.

I have also made a number of long exposures on η *Argûs* with the "Star Camera" (11 feet $3\frac{1}{2}$ inches focus), and succeeded, as the accompanying glass and paper prints will show, in proving that the central part of the nebula about this star has a most complex structure, of the same character as that about θ *Orionis*; but although the greater space given to the nebula in this camera makes the separation of these details possible, I have not yet succeeded in getting so dense and extended a picture of it as I get with the portrait camera, although I have tried one American and another English make of plates; indeed, neither of these makers' plates, judged by the sample I have received, is so sensitive as that which I have been using.

I have compared the plates by having the two cameras side by side on the same stand and pointing to the same place, and then with plates to be compared one in each camera, giving them the same exposure; I had first determined by many trials that the two cameras are about equally powerful.

In the contact print from negative No. 77 it will be seen that the nebula extends but little beyond the well-known oval in the south of it, while in the prints from the portrait camera negative No. 81 the nebula may be seen to extend much farther, and the extension along the great rift spoken of as visible in the photographs from the portrait camera is not to be traced here, but the great dark oval not noticed by Herschel appears very conspicuously in a number of the photographs that I have taken, and must be a feature of the object; it is near the centre of the whole nebula and at the end of the great rift.

It was in this dark oval space that one of the brightest and most conspicuous parts of the nebula was situated when Herschel was at the Cape, and the fact that it has wholly disappeared is a significant commentary on the wisdom of the course which he adopted, in not only drawing but in marking out by conspicuous stars, and by descriptive letter-press, portions of the nebula which were well defined and conspicuous.

The part of the nebula referred to was situated about the intersection of the lines $+50^s$ and $+3000$, and in studying and re-mapping this nebula in 1871 I noticed that this portion was missing. I called attention to it then, but as the telescope I used was of only $7\frac{1}{4}$ inch aperture it could hardly be assumed as proven. Later I failed to find it with the $11\frac{1}{2}$-inch refractor, and it is still invisible in the best of my photographs, which show fainter nebulæ and hosts of stars which Herschel could not see. It is in many respects the most remarkable part of Herschel's drawing, and at p. 39 of the letter-press, after

pointing out the care he had bestowed in laying down parts of the nebula which were well defined by carefully measuring stars situated on or about their edges, and which was done with the expressed object of detecting any change in the nebula, or, to use his own words, "will serve as excellent detectors of change in its form should any occur;" and again, "so situated that the slightest shifting of the nebulous contour at its preceding side cannot fail to be rendered visible;" and then referring to one conspicuous point of the now missing part, he says, "Similarly the star O, No. 803, and O1, No. 813, one on each side of the remarkable nebulous projection whose co-ordinates $+25^s$ and *-2500 pts. afford means of ascertaining any relative movement in this part of it." In other parts of this great nebula these descriptive paragraphs accurately describe the features as they are to-day; and even here the stars are visible, but in the part under discussion there is no such nebula as he describes, either with our equatoreal of $11\frac{1}{2}$ inch aperture, or in these photographs. As a means of estimating how much more powerful in grasping faint objects these photographs are than Herschel's large reflector, I may mention that he carefully scanned the great oval in the southern part of the nebula, and records that he saw four very faint stars in it. My negative, No. 77, shows twenty stars in the same space, and in the lemniscate which attracted his very close attention, and where he saw *one star*, my negative shows ten stars. We have here, therefore, the strongest evidence that a well-defined and brilliant portion of the nebula about *η Argûs* has disappeared between the years 1837 and 1871, when I first noticed that it was gone.

During March 1891 I have taken photographs with a view of tracing the Milky Way in the great rift which Herschel shows right across it in *Argo*, and here, as I have found in other parts, the eye and the camera differ very much.

It will be seen that the three photographs sent (paper and glass positives of each herewith) cover most of the rift in question, and the rough diagram sent herewith of the Milky Way, on the same scale as the photographs copied from Herschel and Proctor, will make the comparison easier. On it the spaces covered by the plates are marked in red ink, and the scales of the photographs and diagram are roughly the same.

The centre of plate 65 is in the preceding point of the four remarkable projections of the Milky Way; its centre is in R.A. $7^h\ 50^m$, and Dec. $47°\ 47'$, and it covers from Dec. $40\frac{1}{2}°$ to $54°$, thus taking in at least $4°$ beyond the remarkable point in the drawings, and it is covered with stars almost uniformly, although the eye sees no Milky Way in that part of the sky covered by the southern end of this plate; or, in other words, the Milky Way here, as seen by the camera, extends right across the rift which to the eye appears void of stars. Similarly plate 73 shows the stars almost uniformly over the plate which here

* This is a misprint; the sign should be +. See position of stars.

covers not only the Milky Way space but the whole of the great rift between R.A. 8^h 10^m and 9^h 10^m, or, in other words, completely across the rift shown in the best drawings. The centre of No. 73 is in R.A. 8^h 37^m and Dec. 46° 53′ S., and it extends from 40° to 54° S. Dec., and taking this with No. 65, the whole of the rift from 7^h 20^m to 9^h 10^m is found to be as thickly studded with stars and star-dust as the neighbouring parts figured on the best star maps. By comparing the overlapping parts of Nos. 65 and 73 it will be seen that 73 does not show quite so many stars as it should, the night it was taken not being so clear as the night on which No. 65 was taken. Plate No. 68, again, shows a band of stars extending completely across the rift from R.A. 10^h 10^m to R.A. 10^h 30^m. The night when this plate was taken was not a very good one, and hence probably here also the stars are not so numerous as they ought to be. On February 9, 1891, the night being very clear, a negative of *Nubecula Major* about 30 *Doradus*, with 6^h 17^m exposure, was taken with the Star Camera, 11 feet $3\frac{1}{2}$ inches focus. In this negative the central part of the nebula is over-exposed, but the surroundings show out faintly as a most complex structure, and are fairly reproduced in the thin contact print No. 2; their extent is at least eight times as great as that which the central mass covers when seen through the telescope. These faint outlying portions are of the same character as the parts visible to the eye; that is, a series of loops arranged symmetrically with regard to the central mass: the greatest extension is on the preceding side, where it stretches out nearly three times the width of the part seen with the telescope, and on the south side there can be traced very faintly a large oval dark space outlined by the nebula and as long as the whole of the central mass.

In No. 1 these features of the nebula have been sacrificed to make the stars bright on a black ground. The arrangement of the stars here is most unusual; the great groups are very concentrated, without any signs of spiral structure, and these clusters, all of which are elongated, are roughly parallel with each other, and separated by dark bands, which, however, are not without stars. I have not seen a similar structure in any other part of the heavens, and the stars are much closer together than usual. In places they number at the rate of 5,000 or 6,000 to a square degree, so that it is not surprising to find the dense parts run into blotches of light when photographed with the portrait camera.

On these Star Camera plates $1° = 2^{in.}360$, and on those taken with the portrait camera $1° = 0^{in.}556$.

The photographs are placed in the Library.

Examples of Comparative Photographs of the Metallic and Solar Spectra. By F. McClean, M.A.

The photographs represent the spectra of Sections IV., V., and VI. of the Gold Group of Metals and of Section IV. of the Iron Group. These spectra are collated by means of their common air lines with the iron spectrum, and so by means of the iron lines with the solar spectrum.

The sections correspond with the divisions of Ångström's Chart. Section VI. extends to wave-length 5720 (a little short of D), which is as far towards the Red as the photographs can be, at present, satisfactorily obtained. The exposure requisite with the more refractory metals is something like sixty times as long as is necessary for photographs of the corresponding portions of the solar spectrum, although an extremely powerful induction spark is used.

These photographs are probably among those which offer the greatest difficulty in the series of metallic spectra now in hand, and as the undertaking is one requiring considerable time and labour, I wished meanwhile to bring these examples of the work before the Society.

The spectra of the metals appear to me to be fairly within the scope of astronomy, as our knowledge of them forms the basis of any knowledge we possess of the composition of the heavenly bodies.

The spectra of the Gold Group, as far as the photographs go, indicate many lines due to these metals not hitherto observed, and they also show some curious coincidences between the air lines in the metallic spectra and lines in the solar spectrum.

1891 *June* 11.

Observations of the Partial Solar Eclipse of 1891 *June* 6, *made at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, M.A., F.R.S.*)

The observations of first contact were lost owing to cloud. The last contact was satisfactorily observed.

Greenwich Mean Time.			Observer.	Instrument.	Power.	Ref.
h	m	s				
6	22	46·4	Wickham	Barclay, 10-inch	90	(*a*)
6	22	47·8	Robinson	Heliometer, $7\frac{1}{2}$-inch	140	(*b*)

(*a*) The time given is that of the last trace of the Moon's limb: phenomenon slow, limbs undulating, but observation good.

(*b*) The time noted is that of the final disappearance of the Moon's limb; observation considered very fair.

Radcliffe Observatory, Oxford:
1891 *June* 11.

Observations of the Transit of Mercury on 1891 May 9 at the Royal Observatory, Edinburgh.

(*Communicated by Ralph Copeland, Ph.D., Astronomer Royal for Scotland.*)

The sky was very clear in the neighbourhood of the Sun, and at a moderate elevation the definition was excellent as tested before the egress on *Jupiter*, and afterwards on various sun-spots. But at the very low altitude of *Mercury*, which was only 2° 44′ above the true horizon at internal contact, the case was far different. Examined with the 24-inch reflector, and a power of 138 on 4 inches of free aperture just clear of the diagonal mirror, the Sun's limb was deeply indented with slow, creeping undulations. Some of these indentations occasionally deformed the same point of the Sun's margin for a second or more at a time, giving it a kind of scolloped appearance. From comparisons with the planet's diameter, it was estimated that the larger of these indentations were fully 3″ deep. They differed very much in length, but 1′ may be taken as the average; some, however, were quite as short as 12″, and the crest of one of these short waves was seen to turn over for a second or so into a distinct hook almost enclosing a dark area not unlike the disc of the planet. The undulations seemed chiefly to move along the Sun's limb in the direction of decreasing position-angle, that is to say, downwards, the position-angle of the planet counted from the Sun's vertex being 223°.

As seen in the reflector, the Sun's limb appeared to be torn asunder rather suddenly by the planet's disc at $19^h\ 40^m\ 40^s$ sidereal clock time, but the outline of the Sun was so unsteady that for about a quarter of a minute it looked as if the Sun's limb might reunite at any moment; but this did not happen, and the above time was adopted as that of internal contact.

At external contact the Sun's limb was watched for 22^s after the recorded time, but no further trace of the planet was seen. The planet's true altitude at this contact was 3° 17′.

Mr. Heath observed with his own $3\frac{1}{2}$-inch Cooke achromatic, while Mr. A. J. Ramsay used the 3·7-inch Sheepshanks telescope, reduced in aperture, on a portable equatorial stand.

The observations, arranged in order of time, run as follows:—

	Edinburgh M.T.	Effective Aperture.	Power.	Observer.
	h m s	ins.		
Internal contact ...	16 28 50·1	4	138	R. C.
,, ...	16 28 58·1	$2\frac{7}{8}$	48	A. J. R.
Planet bisected ...	16 31 4·7	4	138	R. C.
,, ...	16 31 51·6	$3\frac{1}{2}$	120	T. H.
External contact ...	16 32 49·4*	$2\frac{7}{8}$	48	A. J. R.
,, ...	16 33 9·4	$3\frac{1}{2}$	120	T. H.
,, ...	16 33 42·3	4	138	R. C.

* Observer's Note: 'The last contact was estimated to have taken place when I could no longer distinguish between the undulations of the Sun's limb and the notch made by the disappearing planet.'

The Transit of Mercury, 1891 *May* 9, *observed at Sydney Observatory.*

(*Communicated by H. C. Russell, B.A., F.R.S., Government Astronomer.*)

The Transit of *Mercury* was satisfactorily observed here to-day. The day was beautifully fine and almost cloudless, but owing to a sudden change of temperature due to a cold southerly wind the definition was not steady. The observations of ingress and egress were made by Mr. R. P. Sellars, who used the large refractor, $11\frac{1}{2}$ O.G., and polarising eyepiece with power of 100. At ingress external contact was observed at $9^h\ 59^m\ 36^s{\cdot}8$.

	h	m	s
Internal contact	10	3	36·8
At egress Internal contact	2	50	43·2
At egress External contact	2	55	21·2

The last contact was considered the most satisfactory, definition being at that moment remarkably good. During the passage thirty-eight micrometer measures were made of the planet's position, and twenty photographs were taken on a scale which makes the Sun's diameter $5\frac{1}{4}$ inches. These are not yet measured or reduced. At noon, as the Sun passed the meridian, both limbs and *Mercury* were observed over seven wires.

I used the finder of the astrophotographic telescope with O.G. $7\frac{1}{2}$ inches. This instrument is in an out-building almost at the ground level, and in it the faulty definition due to atmospheric causes was much worse than in the $11\frac{1}{2}$-in. equatoreal, the latter being raised above the ground 30 feet. Satisfactory observations of ingress could not be made owing to the wavy outline of the Sun at external contact and black drop phenomena at internal contact. The time when I was sure the indent at external contact was *Mercury* was $10^h\ 0^m\ 5^s{\cdot}46$, and the internal contact $10^h\ 4^m\ 1^s{\cdot}76$, but I am sure both these times are late. The egress I was unable to observe. Mr. H. A. Lenehan, first assistant, observing at his own house with a 3-in. telescope, saw external contact at ingress at $9^h\ 59^m\ 45^s{\cdot}0$. Mr. G. D. Hirst, observing at his own house, saw egress with a $3\frac{3}{4}$-in. equatoreal reduced to $2\frac{7}{10}$ in., and dark blue shade, found it impossible to determine the true contact of limbs within 10 seconds owing to the formation of a well-marked black drop, which in the drawing is in length equal to half the diameter of *Mercury*.

Sydney Observatory:
1891 *May* 10.

Observations of the Transit of Mercury, 1891, May 9.
By Professor Kavasgee D. Naegamvala.

The Transit of *Mercury* of May 9 last was observed here on the morning of May 10, civil time. The telescope employed was a Newtonian Reflector (with the silvering removed from the glass parabolic mirror) of $16\frac{1}{2}''$ aperture. No solar eyepiece was used, but a Pritchard's wedge was interposed between the ordinary Huyghenian eyepiece and the eye. The power employed almost throughout was about 130 diameters, as it was found inadvisable to use even the next higher power available, owing to the atmospheric conditions being not of the very best. The limb of the Sun was never observed perfectly quiescent, but throughout it appeared more or less tremulous.

The first part of the transit was not observed, as the Sun rose some time after ingress.

The form of the planetary disc during transit appeared to be circular and of a very inky colour, and comparatively much darker than the brownish-black umbra of the large sun-spot then visible on the luminary.

No inner bright spot was seen on the planet's disk, as noted by most of the previous observers,* but the aureola of light surrounding the disc was, on the other hand, well seen. The aureola was circular, and the thickness of the ring of light was estimated by the eye to be about two-thirds the diameter of the disc itself. It was, moreover, decidedly brighter than the general surface of the Sun, though the intensity of the illumination slightly fell off at the margin of the ring. I may remark that the aureola was best seen when the darkest part of the Pritchard wedge was interposed, and was gradually lost sight of as the wedge was shifted and its lighter portions brought opposite to the eye, even when the depth of colour of the wedge was sufficient to enable the general surface of the Sun to be observed, not only with complete safety, but also with comfort. More than once I had a feeling that the aureola was slightly coronal in character, but I don't lay any stress on it. The aureola was seen up to a very short time of the internal contact at egress, but I did not exactly note the time of its disappearance, as my attention was then directed more to the first formation of the bright ligament and black drop, if any.

The bright ligament was sharply formed, and when just broken the planet's disc at once assumed a pear-like shape. Within two or three seconds, however, a very curious phenomenon was observed. A smaller pear (so to call it), about one-

* The previously recorded observations of the 'bright spot,' as far as I am aware, were all taken with *refractors*, with the exception of a single one, *vide Monthly Notices*, R.A.S., vol. xxix., p. 57, and a doubt, more than once expressed by astronomers, that the phenomenon was an optical one.

third the size of the other and of a lighter tint (i.e. *less black*), was seen to hang outside the limb of the Sun, the "pears" being attached together by their necks in one line. This lasted for about half a minute. The disc of the egressing planet next took the form of a half ellipse, with the semi-minor axis more or less radial; while just before external contact the disc assumed the form of a short and very flat dummy truncated cone with the apex towards the centre of the Sun. The height of the cone gradually grew less and less, till the planet was completely lost to view. The actual external contact was not well observed, owing to the tremulous state of the Sun's limb. For this reason also no time-observations with the chronograph were taken.

The planet could not be observed after egress, though a very careful search was made for it. No appearance resembling that of a satellite was noted during the transit, but it must be remarked here that I was throughout unfortunately prevented from using high powers through unfavourable atmospheric conditions.

The Observatory, College of Science,
Poona, India: 1891 *May* 15.

Note.

Father de Penaranda, Director of the Observatory of the St. Xavier's College, Calcutta, has issued his report, a newspaper reprint of which I beg to enclose. The colour of the planet therein is designated as being of "an intense *purple*-black," while my impression was that it was *inky*-black. The wedges employed by me were alternately two: one that I had received directly from Professor Pritchard, during my visit to European observatories in 1884, and the other was the one I had at the same time purchased from Mr. Hilger. Both of them are of excellent neutral tint; while I am not aware what means were employed by Father de Penaranda to modify the light of the Sun.

Poona: 1891 *May* 21.

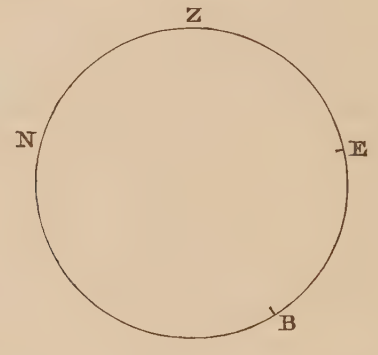
The Transit of Mercury. By the Rev. A. de Penaranda, S.J.

(*Communicated by Prof. K. D. Naegamvala.*)

The Transit of *Mercury* was fairly well observed at St. Xavier's College Observatory, Calcutta, and some good photographs were obtained. The weather, although not all that could have been desired, was more favourable than one would have expected at this season of the year. After a stormy evening and a boisterous night, the Sun rose glorious in a clear sky, and found the three astronomers at their posts making the last adjustments. Both the small and the large equatoreal were put in requisition; the latter, by a special arrangement, giving both a direct and a projected image. The ingress, although visible, could scarcely be said to be properly observable. The Sun then being little more than 5° above the horizon, the boiling at this low altitude was such that it resembled the waves of an agitated sea, among which the tiny black dot's presence could be guessed rather than seen. As far as could be observed or estimated, it was slightly *behind time*, the first external contact taking place at about $5^h\ 51^m$, instead of $5^h\ 50^m\ 3^s$. At egress, the internal contact, despite the very annoying interference of clouds, could be more satisfactorily timed. In fact, there was here a wonderful and rare consensus to the last second of all the observers; from which it appears that the planet now was slightly *before its time*, reaching the Sun's western limb at $10^h\ 17^m\ 17^s$, instead of the computed $10^h\ 18^m\ 49^s$—a difference of $1^m\ 32^s$. Combining this priming with the lagging at ingress, the whole transit seems to have lasted from 2 to $2\frac{1}{2}$ minutes less than computed. This small error of 2 minutes on nearly 5 hours may be accounted for either by some slight imperfection in the astronomical tables of *Mercury*, or by some small excess in the adopted magnitude of the Sun's apparent diameters; or is perhaps owing to a combination of both causes. The planet's aureola was distinctly seen of a decided yellow tinge; the planet itself appearing of an intense purple-black; whereas the spots—even their nuclei—seemed rather of a brownish and notably less deep black. This does not appear to be a mere optical illusion due to contrast, as the photographs bear traces of it. *Mercury*, though to the sight much darker than any nucleus and larger than most of them, but purple, is only slightly marked on the photographs; while small spots, though lighter in colour, but brownish, are much more strongly indicated. The time of the internal contact at ingress could only be approximately estimated on account of the agitation of the Sun's limb; the external contact at egress could not be observed, the Sun being covered by clouds.

On the Transit of Mercury as seen at the G. V. Juggarow Observatory, Daba Gardens, Vizagapatam, May 10, 1891. By A. V. Nursingrow.

The annexed diagram represents the disc of the Sun at the time of the transit, as visible to an observer at Vizagapatam, for direct image.



Z represents the vertex or the highest point of the Sun's disc.

N the north point.

B the point of first contact.
E the point of last contact. } Both internal.

The longitude of the Observatory $=5^h\ 33^m\ 30^s$ E; the geographical latitude $=17°42'9''$ north; and the geocentric latitude $17°35'36''{\cdot}6$.

Clouds were covering the Sun up to $6^h\ 10^m$. When the Sun became visible, we observed that *Mercury* had advanced some distance from the edge of the Sun's disc. The rest of the transit was seen undisturbed by clouds.

The planet was seen as an intensely dark spot when compared with the nuclei of the solar spots then visible.

We did not find a ring of faint light round the planet, neither did we see a wavy tint of light darting from the upper edge of its disc as we noticed during the transit of 1868, p. 278, vol. xxix., *Monthly Notices of the Royal Astronomical Society*, 1869. The telescope now used is a 6-inch refractor by Messrs. Cooke and Sons, equatorially mounted under a revolving dome.

During the whole transit, the planet appeared as a circular dark spot on the Sun's disc. We did not observe that its contour became pear-shaped just before egress; but on reaching the edge of the Sun's disc, it formed a dent quite circular on the

limb. This we took for internal contact at egress = $10^h 17^m 11^s{\cdot}1$ Vizagapatam mean time (civil reckoning). The planet's bisection was observed=at $10^h\ 19^m\ 38^s{\cdot}6$, and the external contact at egress at $10^h\ 22^m\ 6^s{\cdot}8$.

Observatory, Daba Gardens,
Vizagapatam.

Probable Early Observation of an Immersion of Titan.
By Rev. S. J. Johnson.

The observation of a disappearance of *Titan* in *Saturn's* shadow (an event which might again have been witnessed this evening but for intervening clouds), made by Dawes in 1862, was regarded at the time as unique. But in Simonelli's "Scientia Eclipsium," vol. iv. p. 180, there seems to be mention of such a phenomenon being noticed by J. Cassini in 1715. The passage runs as follows: "IV Satelles 1711 die 12 Augusti spectante Blanchino per horam et amplius non apparuit cœlo serenissimo. Certior hujusmodi eclipsis observata fuit a C. J. Cassino in quarto satellite die 25 Martii an. 1715, hor. 11."

Melplash Vicarage, Dorset,
June 6.

Data for computing the positions of the Satellites of Jupiter, 1891. *With Tables of the Inequalities.* By A. Marth.

The selection of the plane of *Jupiter's* equator, in preference to that of the orbit, as the fundamental plane, to which the positions of the satellites are to be referred, offers upon examination such obvious advantages that it is not easy to understand why it has not been adopted long ago in all computations connected with the planet's system.

Let γ and Γ denote the inclination and node of the orbit of a satellite in reference to the adopted fundamental plane, v and l the satellite's true and mean longitude in the orbit, a its mean distance from the planet's centre, $r=a\rho$ its radius vector, v' and b its longitude and latitude in reference to the fundamental plane, $L+180°$ and B the corresponding jovicentric longitude and latitude of the Earth, Δ its distance, $\Lambda+180°$, B and R the analogous coordinates of the Sun. Referring the position of the satellite to three rectangular axes passing through the planet's centre, of which the z axis is the prolongation of Δ, while the x axis is in the fundamental plane, the jovicentric rectangular and polar coordinates of the satellite are, if σ is the

angle between the radius vector and the z axis, and $p-\mathrm{P}$ the position-angle of the radius vector reckoned from the direction of the y axis:

$$(x) = r \sin\sigma \sin(p-\mathrm{P}) = r \cos b \sin(v'-\mathrm{L})$$
$$(y) = r \sin\sigma \cos(p-\mathrm{P}) = r \cos b \cos(v'-\mathrm{L}) \sin \mathrm{B} + r \sin b \cos \mathrm{B}$$
$$(z) = r \cos\sigma \qquad = r \cos b \cos(v'-\mathrm{L}) \cos \mathrm{B} - r \sin b \sin \mathrm{B}.$$

But

$$\cos b \sin(v'-\Gamma) = \sin(v-\Gamma) \cos\gamma$$
$$\cos b \cos(v'-\Gamma) = \cos(v-\Gamma)$$
$$\sin b \qquad = \sin(v-\Gamma) \sin\gamma.$$

Hence

$$r \sin\sigma \sin(p-\mathrm{P}) = r \sin(v-\mathrm{L}) \qquad - r \sin b \,.\, \tan\tfrac{1}{2}\gamma \cos(\mathrm{L}-\Gamma)$$
$$r \sin\sigma \cos(p-\mathrm{P}) = r \cos(v-\mathrm{L}) \sin \mathrm{B} + r \sin b \cos \mathrm{B} - r \sin b \,.\, \tan\tfrac{1}{2}\gamma \sin(\mathrm{L}-\Gamma) \sin \mathrm{B}$$
$$r \cos\sigma \qquad = r \cos(v-\mathrm{L}) \cos \mathrm{B} - r \sin b \sin \mathrm{B} - r \sin b \,.\, \tan\tfrac{1}{2}\gamma \sin(\mathrm{L}-\Gamma) \cos \mathrm{B}.$$

The geocentric angle s between the satellite and the planet's centre and the linear distance Δ' of the satellite from the Earth are found by

$$\Delta' \sin s = r \sin\sigma$$
$$\Delta' \cos s = \Delta + r \cos\sigma.$$

If the plane of *Jupiter's* equator is made the fundamental plane, the last terms in the expressions of the coordinates are very small, and the geocentric coordinates become, as the term $\nu \sin b \sin \mathrm{B}$ is not appreciable in Δ'

$$\Delta' = \Delta + a\rho \cos(v-\mathrm{L}) \cos \mathrm{B}$$
$$x'' = s \sin(p-\mathrm{P}) = \frac{a''}{\Delta'} \,.\, \rho\,[\sin(v-\mathrm{L}) - \sin(v-\Gamma) \sin\gamma \tan\tfrac{1}{2}\gamma \cos(\mathrm{L}-\Gamma)]$$
$$y'' = s \cos(p-\mathrm{P}) = \frac{a''}{\Delta'} \,.\, \rho\,[\cos(v-\mathrm{L}) \sin \mathrm{B} + \sin(v-\Gamma) \sin\gamma \cos \mathrm{B}],$$

where

$$a'' = a\omega'' = \frac{a}{\text{arc } 1''},$$

and where the second term in the expression of x'' may be usually discarded, since at its maximum it does not amount to more than $0''{\cdot}01$ for Sat. II. and IV., and is quite insensible for Sat. I. and III.

By means of these formulæ accurate positions of the satellites may be readily computed if the data and tables required for the purpose are supplied; and the equations between observed and computed positions and the corresponding variations of the elements from which the data are derived may

also be easily formed. If rectangular coordinates, or differences of coordinates, parallel to the axes of *Jupiter's* disc, are measured, care ought to be taken that they are measured in the directions of the computed position-angles P + 90° and P, and that the directions used should be properly read off and stated, so that any needed reductions may be duly applied. The equations for rectangular coordinates are

$$\delta x'' = \frac{a}{\Delta'} \cdot \rho \cos (v - \mathrm{L})\, \delta v + x'' \cdot \frac{\delta r}{r}$$

$$\delta y'' = \frac{a}{\Delta'} \rho \left[-\sin (v - \mathrm{L}) \sin \mathrm{B} + \cos (v - \Gamma) \sin \gamma \cos \mathrm{B} \right] \delta v$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \sin v . \delta (\gamma c)$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \cos v . \delta (\gamma s)$$

$$+ y'' \cdot \frac{\delta r}{r},$$

where γc is written for $\gamma \cos (\mathrm{O} - \Gamma)$, and γs for $\gamma \sin (\mathrm{O} - \Gamma)$, O being the point from which the longitudes are reckoned. The variation δv represents the variations of the mean longitude δl and of the chief inequalities on which the determination of the masses of the satellites and of the eccentricities of their orbits depends, and must be considered specially for each satellite.

If, instead of the rectangular coordinates x'' and y'', the polar coordinates s and p are furnished by the measurements, the equations between the observed and computed positions and the variations of the elements become

$$\delta s = \frac{a}{\Delta'} \rho \cos \mathrm{B} \left[\sin (p - \mathrm{P}) \cos \sigma + \cos (p - \mathrm{P}) \cos (v - \Gamma) \sin \gamma \right] . \delta v$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \frac{\cos (p - \mathrm{P})}{\sin \sigma} \cdot \sin v . \delta (\gamma c)$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \frac{\cos (p - \mathrm{P})}{\sin \sigma} \cdot \cos v . \delta (\gamma s)$$

$$+ s \cdot \frac{\delta r}{r}$$

$$s \delta p = \frac{a}{\Delta'} \rho \cdot \frac{\sin \mathrm{B} + \sin \gamma \sin (\mathrm{L} - \Gamma) \cos \mathrm{B}}{\sin \sigma} \cdot \delta v$$

$$- \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \sin (p - \mathrm{P}) \cdot \sin v . \delta (\gamma c)$$

$$- \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \sin (p - \mathrm{P}) \cdot \cos v . \delta (\gamma s).$$

With the requisite modifications, the equations are also applicable for the computation of the transits of the satellites across the planet's disc and of their occultations by the disc.

The substitution of the coordinates of the Sun for those of

the Earth gives the equations of the jovicentric coordinates of the satellite referred to the axis of the shadow-cone of *Jupiter* as the z axis.

$$r \sin \sigma \sin \pi = a\rho \sin (v-\Lambda) \qquad -a\rho \sin (v-\Gamma) \,.\, \sin \gamma \tan \tfrac{1}{2}\gamma \cos (\Lambda-\Gamma)$$

$$r \sin \sigma \cos \pi = a\rho \cos (v-\Lambda) \sin B + a\rho \sin (v-\Gamma) \,.\, \sin \gamma \cos B$$

$$r \cos \sigma \qquad = a\rho \cos (v-\Lambda) \cos B - a\rho \sin (v-\Gamma) \,.\, \sin \gamma \sin B,$$

where π is the position-angle of r reckoned from the y axis.

The distance $r \sin \sigma$ of the satellite from the axis of the shadow-cone must then be compared with the corresponding radius of the section of the shadow which passes through the point $r \cos \sigma$ of the z axis, or rather with the corresponding radii of the three cones, of which one has its point in the centre of the Sun and envelopes *Jupiter's* spheroid, while the others are the two edge-cones which envelope the Sun and *Jupiter*, and which represent the geometrical outline of the umbra and penumbra. However, as it seems desirable to illustrate some further remarks by a practical application to observed eclipses, I postpone these remarks on eclipses, and also on transits of the shadows of satellites across the planet's disc, till I shall have had the opportunity of computing some of the eclipses, which, it is to be expected, will be observed photometrically as well as in the usual way during the present apparition of *Jupiter*.

The question what values of the elements of the orbits and of the inequalities are available, which approach so near to the true ones that they may be confidently adopted in the computations, is beset with considerable doubt. Our present knowledge of *Jupiter's* system is in a curiously unsatisfactory state. While almost all other branches of astronomical science have made great progress during the last half-century, while especially the orbits of all the other satellites have become better known, there has been practically no growth in our knowledge of the motions of the satellites of *Jupiter*. The cause of this backwardness can be traced clearly enough, and it is high time that it should be pointed out unreservedly, so that it may at last be got rid of. The chief obstacle in the way of progress has been the mistaken notion that the predictions of the times of the eclipses must be made by means of special eclipse tables, and that for the purpose of continuing these predictions it is necessary to construct continuations of such tables. None of the offices at which the predictions are computed has ventured to leave the narrow artificial track prescribed by Damoiseau's tables, and to follow instead an independent course, the adoption of which, while readily allowing any degree of attainable accuracy in the predictions of the times of eclipses and other phenomena, would also have provided the means for computing accurate places of the satellites, and for rendering the results of the observations available for correcting the assumed elements and other constants. In consequence of such means not having been furnished in any

of the ephemerides, the great mass of observations of the satellites made during the last half-century has hitherto remained uncomputed, and has not yet been made contributory to our better knowledge of *Jupiter's* system. Moreover, the results deduced by Delambre and Damoiseau from preceding observations of eclipses have had to be accepted simply upon trust, for the evidence upon which they are founded is unknown. Delambre's statement on page iv of his "Tables Ecliptiques des Satellites de *Jupiter*," Paris, 1817, "Si je ne puis espérer de faire moi-même ces améliorations, je tâcherai du moins de laisser les matériaux dans un ordre assez clair et assez commode pour que le travail puisse être continué sans qu'on soit obligé de recommencer les calculs des anciennes éclipses, . . ." leaves room for hope that there may still exist some MS. of his which might throw considerable light upon his labours, and a search for which might not be fruitless. The regret, which Bessel expressed, 1842 (*Astron. Untersuchungen*, vol. ii. pp. 27 and 25) respecting the insufficiency of the information to be found in the introduction of Damoiseau's tables and his apprehension of the consequences have been only too well justified. There exists a MS. of Damoiseau in explanation of his tables, which Professor Souillart has had at his service; but it does not seem to throw any light upon some deficiencies or inconsistencies in Damoiseau's statements, which require to be cleared up.

I have long been desirous to extend the ephemerides for physical observations of *Jupiter*, which I have given since 1872 (the first ones for the oppositions of 1872–74 anonymously in the *Astron. Register*, the following ones since the opposition of 1875 in the *Monthly Notices*), so as to make them available for computing the positions of the satellites; but want of time and also the expectation that better materials to work with than Damoiseau's would be accessible before long prevented my doing so. The incidental statement by Professor Darwin (*Monthly Notices*, vol. 37, p. 81, footnote ‡) of the masses of the satellites which Professor Adams had determined, and which indicated that he was at work on the whole problem, induced me to postpone further proceedings, and to give merely the values of the inclinations and nodes of the orbits referred to *Jupiter*'s equator. Meanwhile Professor Souillart's interesting investigations have been published in vol. 45 of the *Memoirs of the Royal Astronomical Society*, and in vol. 30 of the *Mémoires présentés par divers savants à l'Académie des Sciences de l'Institut de France*. If the adoption of Professor Souillart's final values of the inequalities of the motions of the satellites and of the variations of the elements, as given on pp. 180 to 193 of the latter publication is not free from doubts and misgivings, it is chiefly because they are founded upon Damoiseau's data, which are not sufficiently trustworthy for the purpose. As an instance, I may mention the doubt concerning the mass of the fourth satellite. The determination of this mass depends greatly on the determination

of the coefficient of sin $(l_3 - \varpi_4)$ (the angle between the mean longitude of Sat. III. and the apse of Sat. IV.), an inequality in the motion of the third satellite. Delambre finds from observation the value of this coefficient $116^s.76$ from which Laplace deduces the mass of Sat. IV. Damoiseau reduces the coefficient from $116^s.76$ to $65°.073$, but alters the mass of Sat. IV. only slightly. His values of the coefficient and of the mass are inconsistent with each other. Professor Adams appears to have satisfied himself that Damoiseau's coefficient is right, and that consequently his mass of Sat. IV. is wrong, and he reduces the mass accordingly by about one-half. Professor Souillart, on the other hand, assumes the correctness of Damoiseau's mass and deduces a coefficient approaching that of Delambre. The question, which is the correct coefficient and the correct mass, can only be decided by an extended discussion of the observations. The discrepancies between the coefficients of the chief inequalities, as determined by Souillart and by Damoiseau from approximately the same elements, are so considerable that it is clear that their true values must first be trustworthily deduced from the observations before a refined theory can be securely built upon them.

The values of P, L, B, Λ, *B*, which are required for the application of the formulæ for computing the positions of the satellites, are already published in the "Ephemeris for Physical Observations of *Jupiter*," in the present volume of the *Monthly Notices*, p. 360 ff. The adopted fundamental plane depends on Souillart's assumed node and inclination for 1850, and on his values of the shifting of the equator on the orbit (found on p. 157 of the second Memoir), but with the substitution of the precession adopted by Le Verrier for that of Delambre.

The longitude of the node and the inclination of the fundamental plane in reference to the movable plane of *Jupiter's* orbit, as given in Le Verrier's Tables, are—

	Node O.	Inclination.
	° ′ ″	° ′ ″
1880 Apr. 14	135 10 13·24	3 4 4·27
1890 Feb. 21	135 18 0·83	4·51
1900 Jan. 0	135 25 48·43	3 4 4·75

and in reference to the ecliptic—

	Long. of Node.	Inclination.	Long. of O.
	° ′ ″	° ′ ″	° ′ ″
1880 Apr. 14	336 6 15·55	2 8 57·11	135 11 27·31
1890 Feb. 21	336 13 51·99	2 9 0·53	135 19 14·93
1900 Jan. 0	336 21 28·39	2 9 3·94	135 27 2·55

The values of the node N, the inclination I, and the longitude of O (or N+NO), referred to the plane parallel to the

Earth's true equator, which have served for the computation of P, L—O, and B, are—

	N.	I.	N+NO.
1891 Apr. 17	−2°·0169	25°·4364	135°·1508
May 17	2·0169	·4363	·1519
June 16	2·0168	·4363	·1533
July 16	2·0166	·4365	·1548
Aug. 15	2·0165	·4367	·1560
Sept. 14	−2·0164	25·4368	135·1570
Oct. 14	2·0164	·4369	·1578
Nov. 13	2·0163	·4368	·1588
Dec. 13	2·0162	·4368	·1602
1892 Jan. 12	2·0161	·4369	·1617
Feb. 11	−2·0160	25·4371	135·1630

As the mean and true longitudes l and v and the longitudes ϖ of the lower apses of the orbits of the different satellites are here distinguished by having the number of the satellite attached (as in Delambre's and Damoiseau's Tables), it will be useful to state expressly the corresponding notation of Professor Souillart.

$l_1\ l_2\ l_3\ l_4 = l\ l'\ l''\ l'''$ of Souillart

$v_1\ v_2\ v_3\ v_4 = v\ v'\ v''\ v'''$ „

$\varpi_1 = g\,t + \beta$ $\quad$ $G_1 = b_4 t + \gamma_4 - b\,t - \gamma$ of Souillart

$\varpi_2 = g_1 t + \beta_1$ $\quad$ $G_2 = b_4 t + \gamma_4 - b_1 t - \gamma_1$

$\varpi_3 = g_2 t + \beta_2$ $\quad$ $G_3 = b_4 t + \gamma_4 - b_2 t - \gamma_2$

$\varpi_4 = g_3 t + \beta_3$ $\quad$ $G_4 = b_4 t + \gamma_4 - b_3 t - \gamma_3$

The values of ϖ—O and of G adopted in the preparation of the tabular data are the following:

	ϖ_1−O.	ϖ_2−O.	ϖ_3−O.	ϖ_4−O.
1891 Apr. 17	210°·5295	38°·2069	204°·2501	146°·4513
June 16	219·4845	40·8208	204·6819	146·5690
Aug. 15	228·4394	43·4348	205·1138	146·6868
Oct. 14	237·3944	46·0487	205·5456	146·8046
Dec. 13	246·3494	48·6626	205·9774	146·9224
1892 Feb. 11	255·3043	51·2765	206·4093	147·0401

	G_1	G_2	G_3	G_4
1891 Apr. 17	126°·92	295°·1469	322°·4955	303°·5860
June 16	135·39	297·1275	322·9166	303·6999
Aug. 15	143·86	299·1081	323·3378	303·8138
Oct. 14	152·32	301·0887	323·7589	303·9278
Dec. 13	160·79	303·0693	324·1801	304·0417
1892 Feb. 11	169·25	305·0498	324·6012	304·1556

The mean longitudes $l-O$ of the satellites, given for Greenwich noon at intervals of ten days, have been so adjusted that, while the altered constant of the velocity of light is allowed for, and also some plausible corrections have been adopted, the corrected values for the epoch 1750 have been only slightly altered. The resulting mean daily motions

of l_1-O are	203°·4889560
l_2-O	101·3747256
l_3-O	50·3176104
l_4-O	21·5710740

The columns headed S_1, S_2, S_3, S_4 contain the sums of all the inequalities in longitude, which are independent of the longitudes of the satellites, and consist of the following terms, the coefficients of which are those of Professor Souillart:

Coefficients of S_1	S_2	S_3	S_4	
+ 2″·206	− 36″·617	− 48″·470	− 115″·012	× sin M
− 0·176	− 3·033	− 4·416	− 10·425	× sin W
...	− 0·336	− 0·475	− 1·122	× sin W_1
− 35·839	− 10·167	− 0·204	...	× sin G_2
...	− 5·682	− 8·509	+ 6·187	× sin G_3
+ 0·436	− 6·044	− 9·284	− 3·241	× sin G_4
− 9·459	− 3·929	− 1·677	...	× sin (G_2-G_3)
+ 3·536	− 1·541	− 4·072	− 3·150	× sin (G_3-G_4)
− 1·488	− 0·550	− 0·196	...	× sin (G_2-G_4)
− 1·320	+ 0·464	+ 2·388	− 2·886	× sin $(\varpi_3-\varpi_4)$

where M denotes the mean anomaly of *Jupiter*, and W and W_1 the values of $5l^V-2l^{IV}-16°\ 38'$ and $l^{IV}-2l^V-1°\ 30'$ in the notation of Le Verrier's Tables.

Before explaining the arguments, the equations may be stated by which the values of γ and $O-\Gamma$, given at the bottom of the pages, have been computed. They are—

$$\gamma_1 \sin(O-\Gamma_1) = \quad'' \quad - 33''{\cdot}035 \sin G_2 - 3''{\cdot}914 \sin G_3 + 1''{\cdot}394 \sin G_4 - 0{\cdot}915 \sin V - 4{\cdot}803 \sin G_1$$

$$\gamma_1 \cos(O-\Gamma_1) = 7{\cdot}24 - 33{\cdot}035 \cos G_2 - 3{\cdot}914 \cos G_3 + 1{\cdot}394 \cos G_4 - 0{\cdot}915 \cos V - 4{\cdot}803 \cos G_1$$

$$\gamma_2 \sin(O-\Gamma_2) = \quad'' \quad - 1689''{\cdot}882 \sin G_2 - 102''{\cdot}264 \sin G_3 - 15''{\cdot}711 \sin G_4 - 2{\cdot}817 \sin V - 0{\cdot}372 \sin(V-G_2)$$

$$\gamma_2 \cos(O-\Gamma_2) = 64{\cdot}34 - 1689{\cdot}882 \cos G_2 - 102{\cdot}264 \cos G_3 - 15{\cdot}711 \cos G_4 - 2{\cdot}817 \sin V - 0{\cdot}372 \cos(V-G_2)$$

$$\gamma_3 \sin(O-\Gamma_3) = \quad'' \quad + 57''{\cdot}437 \sin G_2 - 644''{\cdot}173 \sin G_3 - 97''{\cdot}328 \sin G_4 - 6{\cdot}389 \sin V - 0{\cdot}368 \sin(V-G_3)$$

$$\gamma_3 \cos(O-\Gamma_3) = 295{\cdot}07 + 57{\cdot}437 \cos G_2 - 644{\cdot}173 \cos G_3 - 97{\cdot}328 \cos G_4 - 6{\cdot}389 \cos V - 0{\cdot}368 \cos(V-G_3)$$

$$\gamma_4 \sin(O-\Gamma_4) = \quad'' \quad + 1{\cdot}546 \sin G_2 + 125''{\cdot}267 \sin G_3 - 811''{\cdot}414 \sin G_4 - 13{\cdot}694 \sin V - 1{\cdot}145 \sin(V-G_4)$$

$$\gamma_4 \cos(O-\Gamma_4) = 1449{\cdot}35 + 1{\cdot}546 \cos G_2 + 125{\cdot}267 \cos G_3 - 811{\cdot}414 \cos G_4 - 13{\cdot}694 \cos V - 1{\cdot}145 \cos(V-G_4),$$

where V is written for $2(O-\Lambda)$, and where the constants in the cos terms vary slightly, the correction for 1880 April 14 being $-0''{\cdot}48$, and for 1900 0.

The arguments of the inequalities represent the following angles:

$\alpha_1 = 2(l_1 - l_2) = 4\beta_1$
$\beta_1 = l_2 - l_3 + 180°$
$\gamma_1 = l_1 - \varpi_1$
$\delta_1 = l_1 - \varpi_3$
$\epsilon_1 = l_2 - 2l_3 + \varpi_1 + 180°$
$\zeta_1 = l_2 - 2l_3 + \varpi_2$
$\eta_1 = l_2 - 2l_3 + \varpi_3$
$\theta_1 = l_2 - 2l_3 + \varpi_4$

$\alpha_2 = l_1 - l_2 = 2\beta_2$
$\beta_2 = l_2 - l_3 + 180° = \beta_1$
$\gamma_2 = l_2 - \varpi_2$
$\delta_2 = l_2 - \varpi_3$
$\epsilon_2 = l_2 - \varpi_4$
$\zeta_2 = l_2 - 2l_3 + \varpi_2 = \zeta_1$
$\eta_2 = l_2 - 2l_3 + \varpi_3 + 180°$
$\theta_2 = l_2 - 2l_3 + \varpi_4 + 180°$
$\iota_2 = l_2 - 2l_3 + \varpi_1 = \epsilon_1 + 180°$
$\kappa_2 = 2l_1 - 3l_2 + \varpi_3$
$\lambda_2 = 2l_1 - 3l_2 + \varpi_4$

$\alpha_3 = l_3 - \varpi_3$
$\beta_3 = l_3 - \varpi_4$
$\gamma_3 = l_2 - l_3 + 180° = \beta_1$
$\delta_3 = l_3 - l_4 + 180°$
$\epsilon_3 = 2l_2 - 3l_3 + \varpi_3 + 180°$
$\zeta_3 = l_2 - 2l_3 + \varpi_2$
$\eta_3 = l_2 - 2l_3 + \varpi_3$
$\theta_3 = l_2 - 2l_3 + \varpi_4$
$\iota_3 = l_3 - \varpi_2 + 180°$

$\alpha_4 = l_4 - \varpi_4$
$\beta_4 = l_3 - l_4 + 180° = \delta_3$
$\gamma_4 = l_4 - \varpi_3 + 180°$
$\delta_4 = l_4 - 2l_0 + \varpi_4$
$\epsilon_4 = 2(l_4 - l_0)$
$\zeta_4 = l_3 - 2l_4 + \varpi_4$
$\eta_4 = l_2 - l_4$
$\theta_4 = l_3 - 2l_4 + \varpi_3 + 180°$

l_0 in δ_4 and ϵ_4 denotes the heliocentric mean longitude of ♃, reckoned from O.

These arguments are expressed in parts of the circumference of the circle.

For each satellite are then given the motions of the longitudes and of the arguments for every six hours of the interval of ten days, and for every ten minutes of the interval of six hours.

The arguments furnish then the equivalents of the inequalities, which are composed as follows:

First Satellite.

Radius Vector.		Longitude.	
$\rho_1 =$ 1·0000 096	Arg.	$v_1 = l_1 +$ 1554″·759 sin α_1	Arg.
− ·0037 751 cos α_1		+ 5·029 sin $2\alpha_1$	α_1
− 119 cos $2\alpha_1$	α_1	+ 12·357 sin $2\beta_1$	
− ·0000 607		− 6·268 sin $3\beta_1$	β_1
− ·0000 173 cos $2\beta_1$		+ 8·796 sin γ_1	γ_1
+ 121 cos $3\beta_1$	β_1	+ 8·145 sin δ_1	δ_1
+ 294		+ 11·000 sin ϵ_1	ϵ_1
− 213 cos γ_1		+ 23·041 sin ζ_1	ζ_1
+ 213	γ_1	+ 19·689 sin η_1	η_1
− 196 cos δ_1		+ 10·179 sin θ_1	θ_1
+ 196	δ_1		

Second Satellite.

Radius Vector.		Longitude.	
$\rho_2 =$ 1·0000 421	Arg.	$v_2 = l_2 +$ 3692″·981 sin α_2	Arg.
− ·0090 095 cos α_2		+ 22·434 sin $2\alpha_2$	α_2
− 456 cos $2\alpha_2$	α_2	+ 1·491 sin $3\alpha_2$	
+ 062 cos $3\alpha_2$		+ 48·578 sin β_2	
− ·0005 060		− 20·498 sin $2\beta_2$	β_2
− ·0000 672 cos β_2		− 1·505 sin $3\beta_2$	
+ 634 cos $2\beta_2$		+ 45·246 sin γ_2	γ_2
+ 061 cos $3\beta_2$	β_2	+ 79·680 sin δ_2	δ_2
+ ·0000 770		+ 42·593 sin ϵ_2	ϵ_2
− ·000 1096 cos γ_2		+ 95·284 sin ζ_2	ζ_2
+ 1096	γ_2	+ 120·671 sin η_2	η_2
− ·000 1931 cos δ_2		+ 62·966 sin θ_2	θ_2
+ 1931	δ_2	+ 6·609 sin ι_2	ι_2
− ·000 1032 cos ϵ_2		+ 6·947 sin κ_2	κ_2
+ 1032	ϵ_2	+ 3·624 sin λ_2	λ_2
− ·000 0152 cos κ_2			
+ 152	κ_2		
− ·000 0079 cos λ_2			
+ 79	λ_2		

Third Satellite.

Radius Vector.		Longitude.	
$\rho_3 =$ 1·0000 009	Arg.	$v_3 = l_3 +$ 462″·880 sin α_3	Arg.
− ·0011 219 cos α_3	α_3	+ (0·324 sin $2\alpha_3$)	α_3
− 010 cos $2\alpha_3$		+ 241·905 sin β_3	β_3
− ·0013 050		+ (0·339 sin $2\beta_3$)	
− ·0005 864 cos β_3	β_3	+ 228·473 sin γ_3	γ_3
− 008 cos $2\beta_3$		− 4·084 sin $2\gamma_3$	
+ ·0005 872		+ 2·097 sin $3\gamma_3$	
− ·0005 827 cos γ_3	γ_3	− 0·286 sin $4\gamma_3$	
+ 155 cos $2\gamma_3$		+ 14·620 sin δ_3	δ_3
+ 024 cos $3\gamma_3$		+ 49·710 sin $2\delta_3$	
+ 014 cos $4\gamma_3$		− 3·503 sin $3\delta_3$	
+ ·0005 634		+ 0·814 sin $4\delta_3$	
− ·0000 221 cos δ_3	δ_3	− 0·258 sin $5\delta_3$	
− ·0001 320 cos $2\delta_3$		+ 2·012 sin ϵ_3	ϵ_3
+ 117 cos $3\delta_3$		+ 15·816 sin ζ_3	ζ_3
− 031 cos $4\delta_3$		+ 23·602 sin η_3	η_3
+ 011 cos $5\delta_3$		+ 12·062 sin θ_3	θ_3
+ ·0001 444		+ 1·936 sin ι_3	ι_3
− ·0000 050 cos ϵ_3	ϵ_3		
+ 50			
− ·0000 050 cos ι_3	ι_3		
+ 050			

For the sake of proper arrangement, the small second terms of the inequalities in longitude depending on α_3 and β_3 have been omitted and the columns transferred.

Fourth Satellite.

Radius Vector.		Longitude.	
$\rho_1 =$ 1·0000 265	Arg.	$v_4 = l_4 +$ 2995″·688 sin α_4	Arg.
− ·0072 597 cos α_4	α_4	+ 13·592 sin $2\alpha_4$	α_4
− 264 cos $2\alpha_4$		+ 9·189 sin β_4	β_4
− ·0003 204		− 4·571 sin $2\beta_4$	
− ·0001 105 cos β_4	β_4	+ 0·951 sin $3\beta_4$	
+ 201 cos $2\beta_4$		+ 59·063 sin γ_4	γ_4
− 047 cos $3\beta_4$		+ 22·527 sin δ_4	δ_4
+ ·0000 951		+ 2·208 sin ϵ_4	ϵ_4
− ·0001 431 cos γ_4	γ_4	+ 2·535 sin ζ_4	ζ_4
+ ·0001 431		+ 1·682 sin η_4	η_4

Fourth Satellite.

Radius Vector.

$$\rho_4 = \cdot0000\ 547 \cos \delta_4 + 547 \quad \delta_4$$
$$- \cdot0000\ 148 \cos \epsilon_4 + 148 \quad \epsilon_4$$
$$- \cdot0000\ 043 \cos \zeta_4 + 043 \quad \zeta_4$$
$$+ \cdot0000\ 084 \cos \eta_4 + 084 \quad \eta_4$$

Longitude.

$$v_4 = l_4 + 1''\cdot688 \sin \theta_4 \quad \text{Arg. } \theta_4$$

The inequalities of the radius vector, which Professor Souillart expresses in semi-diameters of *Jupiter's* equator, have been converted into those of the mean distance as unit by employing the values given on p. 10 of his Memoir.

The values of log a and log a'', corresponding to various values of the reciprocal of the mass of *Jupiter's* system, are—

$\frac{\text{Mass of Sun}}{\text{Mass of Jupiter}}$	*Sat. I.* log a_1	log a_1''	*Sat. II.* log a_2	log a_2''
1047·0	7·450 202	2·764 627	7·651 885	2·966 310
7·1	188	613	871	296
7·2	174	599	857	282
7·3	160	586	843	268
7·4	147	572	829	254
7·5	133	558	815	241
7·6	119	544	802	227
1047·7	7·450 105	2·764 530	7·651 788	2·966 213
7·8	092	517	794	199
7·9	078	503	760	185
8·0	064	489	746	171
8·1	050	475	733	158
8·2	036	461	719	144
8·3	022	447	705	130
1048·4	7·450 009	2·764 434	7·651 691	2·966 116

$\frac{\text{Mass of Sun}}{\text{Mass of Jupiter}}$	*Sat. III.* log a_3	log a_3''	*Sat. IV.* log a_4	log a_4''
1047·0	7·854 676	3·169 102	8·099 892	3·414 317
7·1	663	088	878	304
7·2	649	074	865	290
7·3	635	060	851	276
7·4	621	046	837	262
7·5	607	032	823	248
7·6	593	019	809	234

Mass of Sun / Mass of Jupiter	*Sat. III.* log a_3	log a_3''	*Sat. IV.* log a_4	log a_4''
1047·7	7·854 580	3·169 005	8·099 795	3·414 221
7·8	566	3·168 991	782	207
7·9	552	977	768	193
8·0	538	963	754	179
8·1	524	949	740	165
8·2	511	936	726	152
8·3	497	922	713	138
1048·4	7·854 483	3·168 908	8·099 699	3·414 124

The inequalities of the radius vector are given to the sixth decimal of the mean distance as unit, while those of the longitude are given to the fourth decimal of a degree. In order to estimate the accuracy with which the computations have to be made in order to attain the degree of accuracy in the results which may be desired, it is to be considered that a geocentric arc of $0''\cdot01$ corresponds for the distances represented by $\log\Delta = 0\cdot6$ and $0\cdot7$ at the conjunctions to a jovicentric arc of

	Sat. I.	*Sat. II.*	*Sat. III.*	*Sat. IV.*
$\log\Delta = 0\cdot6$	$14''\cdot12$	$8''\cdot87$	$5''\cdot56$	$3''\cdot16$
$0\cdot7$	$17\cdot78$	$11\cdot18$	$7\cdot00$	$3\cdot98$

or of

$\log\Delta = 0\cdot6$	$0^\circ\cdot0039$	$0^\circ\cdot0025$	$0^\circ\cdot0015$	$0^\circ\cdot0009$
$0\cdot7$	49	31	19	14

and at the greatest elongation to an inequality of ρ of

$\log\Delta = 0\cdot6$	·000069	·000041	·000028	·000015
$0\cdot7$	85	53	35	18

while the jovicentric motion of the satellite in one second of time is

$8''\cdot5$ $4''\cdot2$ $2''\cdot1$ $0''\cdot9$.

The inequalities of ρ have all been made positive by the addition of constants, the sum of which has been subtracted from the first term depending on the argument α. If the smaller inequalities are to be neglected, the added constants ought to be added to the first term of ρ.

The inequalities in longitude have the upper or lower sign according as the argument is between ·000 and ·500 or between ·500 and ·000. It will be remarked that the arguments are so chosen that, with the exception of portions of the inequalities depending on β_1, β_2, and δ_3, the inequalities are positive when the argument is to the left, and negative when it is to the right.

First Satellite.

Greenwich Noon.	Longitude.		Arguments.				
	$l_1 - O$	S_1	α_1	β_1	γ_1	δ_1	ϵ_1
1891.	°	°					
Apr. 17	192·1279	+ ·0095	·2206	·305	·949	·966	·272
27	67·0175	95	·8936	·723	·597	·619	·296
May 7	301·9070	94	·5666	·142	·246	·271	·321
17	176·7966	94	·2396	·560	·894	·923	·346
27	51·6862	94	·9126	·978	·542	·575	·370
June 6	286·5757	93	·5857	·396	·191	·228	·395
16	161·4653	+ ·0093	·2587	·815	·839	·880	·420
26	36·3548	93	·9317	·233	·487	·532	·445
July 6	271·2444	92	·6047	·651	·135	·184	·469
16	146·1340	92	·2777	·069	·784	·837	·494
26	21·0235	92	·9507	·488	·432	·489	·519
Aug. 5	255·9131	91	·6237	·906	·080	·141	·543
15	130·8026	+ ·0091	·2967	·324	·729	·794	·568
25	5·6922	91	·9698	·742	·377	·446	·593
Sept. 4	240·5818	90	·6428	·161	·025	·098	·617
14	115·4713	90	·3158	·579	·674	·750	·642
24	350·3609	90	·9888	·997	·322	·403	·667
Oct. 4	225·2504	89	·6618	·415	·970	·055	·691
14	100·1400	+ ·0089	·3348	·834	·619	·707	·716
24	335·0296	89	·0078	·252	·267	·359	·741
Nov. 3	209·9191	88	·6809	·670	·915	·012	·765
13	84·8087	88	·3539	·088	·564	·664	·790
23	319·6982	88	·0269	·507	·212	·316	·815
Dec. 3	194·5878	87	·6999	·925	·860	·969	·840
13	69·4774	+ ·0087	·3729	·343	·509	·621	·864
23	304·3669	86	·0459	·761	·157	273	·889
1892.							
Jan. 2	179·2565	86	·7189	·180	·805	·925	·914
12	54·1460	86	·3919	·598	·454	·578	·938
22	289·0356	85	·0650	·016	·102	·230	·963
Feb. 1	163·9252	85	·7380	·434	·750	·882	·988
11	38·8147	+ ·0085	·4110	·853	·399	·534	·012

	Inclination.	Node.		Inclination.	Node.
	γ_1	$O - \Gamma_1$		γ_1	$O - \Gamma_1$
	°	°		°	°
1891 Apr. 17	0·0079	106·9	1891, Sept. 14	70·0080	108·8
May 17	79	107·3	Oct. 14	81	109·2
June 16	80	107·6	Nov. 13	81	109·6
July 16	80	108·0	Dec. 13	81	110·1
Aug. 15	80	108·4	Jan. 12	82	110·6
Sept. 14	0·0080	108·8	Feb. 11	0·0082	111·1

Greenwich Noon.	*First Satellite.* Arguments.			*Second Satellite.* Longitude.		Arguments.	
1891.	ζ_1	η_1	θ_1	l_2-0	S_2	α_2	β_2
Apr. 17	·293	·754	·594	152°·4208	+·0109	·61030	·305
27	·315	·775	·614	86·1680	·0108	·44680	·723
May 7	·337	·796	·635	19·9153	·0106	·28331	·142
17	·358	·816	·656	313·6626	·0105	·11982	·560
27	·380	·837	·676	247·4098	·0103	·95632	·978
June 6	·402	·858	·697	181·1571	·0102	·79283	·396
16	·424	·879	·717	114·9043	+·0101	·62934	·815
26	·445	·899	·738	48·6516	·0099	·46584	·233
July 6	·467	·920	·759	342·3988	98	·30235	·651
16	·489	·941	·779	276·1461	97	·13886	·069
26	·511	·962	·800	209·8934	95	·97536	·488
Aug. 5	·532	·982	·820	143·6406	94	·81187	·906
15	·554	·003	·841	77·3879	+·0092	·64837	·324
25	·576	·024	·861	11·1351	91	·48488	·742
Sept. 4	·598	·045	·882	304·8824	89	·32139	·161
14	·619	·065	·903	238·6296	88	·15789	·579
24	·641	·086	·923	172·3769	86	·99440	·997
Oct. 4	·663	·107	·944	106·1241	85	·83091	·415
14	·685	·128	·964	39·8714	+·0083	·66741	·834
24	·706	·148	·985	333·6187	82	·50392	·252
Nov. 3	·728	·169	·006	267·3659	80	·34043	·670
13	·750	·190	·026	201·1132	79	·17693	·088
23	·772	·211	·047	134·8604	77	·01344	·507
Dec. 3	·793	·231	·067	68·6077	76	·84994	·925
13	·815	·252	·088	2·3549	+·0074	·68645	343
23	·837	·273	·109	296·1022	72	·52296	·761
1892.							
Jan. 2	·859	·294	·129	229·8494	71	·35946	·180
12	·880	·314	·150	163·5967	69	·19597	·598
22	·902	·335	·170	97·3440	68	·03248	·016
Feb. 1	·924	·356	·191	31·0912	66	·86898	·434
11	·946	·377	·212	324·8385	+·0064	·70549	·853

	Inclination. γ_2	Node. $\Omega-\Gamma_2$	
1891.			
Apr. 17	0°·4919	116°·82	95
May 17	·4919	117·77	94
June 16	·4918	118·71	95
July 16	·4918	119·66	95
Aug. 15	·4917	120·61	95
Sept. 14	·4916	121·56	

Second Satellite.

Greenwich Noon. 1891.	Arguments. γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2
April 17	·317	·856	·017	·293	·254	·094	·772	·365	·204
27	·132	·672	·832	·315	·275	·114	·796	·222	·061
May 7	·947	·488	·648	·337	·296	·135	·821	·079	·918
17	·762	·303	·464	·358	·316	·156	·846	·936	·775
27	·576	·119	·280	·380	·337	·176	·870	·794	·632
June 6	·391	·935	·096	·402	·358	·197	·895	·651	·490
16	·206	·751	·912	·424	·379	·217	·920	·508	·347
26	·021	·566	·728	·445	·399	·238	·945	·365	·204
July 6	·835	·382	·544	·467	·420	·259	·969	·223	·061
16	·650	·198	·360	·489	·441	·279	·994	·080	·918
26	·465	·014	·176	·511	·462	·300	·019	·937	·775
Aug. 5	·280	·829	·992	·532	·482	·320	·043	·794	·632
15	·094	·645	·808	·554	·503	·341	·068	·652	·489
25	·909	·461	·623	·576	·524	·361	·093	·509	·346
Sept. 4	·724	·277	·439	·598	·545	·382	·117	·366	·203
14	·539	·093	·255	·619	·565	·403	·142	·223	·061
24	·353	·908	·071	·641	·586	·423	·167	·081	·918
Oct. 4	·168	·724	·887	·663	·607	·444	·191	·938	·775
14	·983	·540	·703	·685	·628	·464	·216	·795	·632
24	·798	·356	·519	·706	·648	·485	·241	·652	·489
Nov. 3	·612	·171	·335	·728	·669	·506	·265	·510	·346
13	·427	·987	·151	·750	·690	·526	·290	·367	·203
23	·242	·803	·967	·772	·711	·547	·315	·224	·060
Dec. 3	·057	·619	·783	·793	·731	·567	·340	·081	·917
13	·871	·434	·598	·815	·752	·588	·364	·939	·774
23	·686	·250	·414	·837	·773	·609	·389	·796	·632
1892. Jan. 2	·501	·066	·230	·859	·794	·629	·414	·653	·489
12	·316	·882	·046	·880	·814	·650	·438	·510	·346
22	·130	·697	·862	·902	·835	·670	·463	·368	·203
Feb. 1	·945	·513	·678	·924	·856	·691	·488	·225	·060
11	·760	·329	·494	·946	·877	·712	·512	·082	·917

		Inclination. γ_2	Node. $\Omega-\Gamma_2$	
1891	Sept. 14	0°·4916	121°·56	95
	Oct. 14	·4915	122·51	94
	Nov. 13	·4914	123·45	95
	Dec. 13	·4912	124·40	95
1892	Jan. 12	·4911	125·35	95
	Feb. 11	0·4909	126·30	

Third Satellite.

Greenwich Noon. 1891.	Longitude. l_3-O	S_3	Arguments. α_3	β_3	γ_3	δ_3	ϵ_3
	°	°					
April 17	222·5672	+·0113	·0509	·2114	·3051	·388	·992
27	5·7433	·0111	·4484	·6092	·7234	·186	·431
May 7	148·9194	·0110	·8459	·0067	·1417	·985	·870
17	292·0955	·0108	·2434	·4044	·5599	·783	·308
27	75·2716	·0106	·6409	·8021	·9782	·582	·747
June 6	218·4477	·0105	·0384	·1997	·3964	·380	·186
16	1·6239	+·0103	·4360	·5974	·8147	·179	·625
26	144·8000	·0101	·8335	·9950	·2329	·977	·064
July 6	287·9761	·0100	·2310	·3927	·6512	·776	·502
16	71·1522	·0098	·6285	·7903	·0694	·575	·941
26	214·3283	96	·0260	·1880	·4877	·373	·380
Aug. 5	357·5044	94	·4235	·5857	·9059	·172	·819
15	140·6805	+·0093	·8210	·9833	·3242	·970	·258
25	283·8566	91	·2185	·3810	·7424	·769	·696
Sept. 4	67·0327	89	·6160	·7786	·1607	·567	·135
14	210·2088	87	·0136	·1763	·5789	·366	·574
24	353·3849	85	·4111	·5739	·9972	·164	·013
Oct. 4	136·5610	84	·8086	·9716	·4155	·963	·452
14	279·7371	+·0082	·2061	·3693	·8337	·761	·890
24	62·9132	80	·6036	·7669	·2520	·560	·329
Nov. 3	206·0893	78	·0011	·1646	·6702	·358	·768
13	349·2654	76	·3986	·5622	·0885	·157	·207
23	132·4415	74	·7961	·9599	·5067	·955	·646
Dec. 3	275·6176	72	·1936	·3575	·9250	·754	·084
13	58·7937	+·0070	·5912	·7552	·3432	·552	·523
23	201·9698	68	·9887	·1529	·7615	·351	·962
1892. Jan. 2	345·1459	67	·3862	·5505	·1797	·149	·401
12	128·3220	65	·7837	·9482	·5980	·948	·840
22	271·4981	63	·1812	·3458	·0162	·746	·278
Feb. 1	54·6742	61	·5787	·7435	·4345	·545	·717
11	197·8503	+·0059	·9762	·1411	·8527	·343	·156

	Inclination. γ_3	Node. $O-\gamma_3$		Inclination. γ_3	Node. $O-\Gamma_3$
	°	°		°	°
1891 April 17	0·1371	120·41	1891 Sept. 14	0·1360	120·82
May 17	·1369	120·50	Oct. 14	·1357	120·90
June 16	·1367	120·58	Nov. 13	·1355	120·98
July 16	·1364	120·66	Dec. 13	·1352	121·06
Aug. 15	·1362	120·74	1892 Jan. 12	·1349	121·14
Sept. 14	0·1360	120·82	Feb. 11	0·1346	121·22

Greenwich Noon.	*Third Satellite.* Arguments. ζ_3	η_3	θ_3	ι_3	*Fourth Satellite.* l_4-O	Longitude. S_4	Arg. α_4
1891.					°	°	
April 17	·293	·754	·594	·012	262·9352	+·0159	·32357
27	·315	·775	·614	·409	118·6459	·0155	·92271
May 7	·337	·796	·635	·805	334·3567	·0152	·52185
17	·358	·816	·656	·202	190·0674	·0148	·12099
27	·380	·837	·676	·598	45·7781	·0144	·72013
June 6	·402	·858	·697	·995	261·4889	·0140	·31928
16	·424	·879	·717	·391	117·1996	+·0137	·91842
26	·445	·899	·738	·788	332·9104	·0133	·51756
July 6	·467	·920	·759	·184	188·6211	·0129	·11670
16	·489	·941	·779	·581	44·3318	·0125	·71584
26	·511	·962	·800	·977	260·0426	·0121	·31499
Aug. 5	·532	·982	·820	·374	115·7533	·0117	·91413
15	·554	·003	·841	·770	331·4641	+·0113	·51327
25	·576	·024	·861	·167	187·1748	·0109	·11241
Sept. 4	·598	·045	·882	·563	42·8855	·0105	·71155
14	·619	·065	·903	·960	258·5963	·0100	·31070
24	·641	·086	·923	·356	114·3070	·0096	·90984
Oct. 4	·663	·107	·944	·753	330·0178	92	·50898
14	·685	·128	·964	·149	185·7285	+·0088	·10812
24	·706	·148	·985	·546	41·4392	84	·70726
Nov. 3	·728	·169	·006	·942	257·1500	79	·30641
13	·750	·190	·026	·339	112·8607	75	·90555
23	·772	·211	·047	·735	328·5715	71	·50469
Dec. 3	·793	·231	·067	·132	184·2822	66	·10383
13	·815	·252	·088	·528	39·9929	+·0062	·70297
23	·837	·273	·109	·925	255·7037	57	·30212
1892.							
Jan. 2	·859	·294	·129	·321	111·4144	53	·90126
12	·880	·314	·150	·718	327·1252	49	·50040
22	·902	·335	·170	·114	182·8359	44	·09954
Feb. 1	·924	·356	·191	·511	38·5466	40	·69868
11	·946	·377	·212	·907	254·2574	+·0035	·29783

1891.	Inclination. γ_4	Node. $O-\Gamma_4$
	°	°
Apr. 17	0·3455	29·07
May 17	·3457	29·11
June 16	·3460	29·15
July 16	·3462	29·18
Aug. 15	·3465	29·20
Sept. 14	0·3468	29·22

Fourth Satellite.

Greenwich Noon. 1891.	Arguments. β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	θ_4
April 17	·388	·663	·034	·357	·564	·693	·225
27	·186	·262	·628	·551	·764	·910	·424
May 7	·985	·861	·223	·745	·963	·127	·624
17	·783	·460	·818	·939	·162	·343	·823
27	·582	·059	·412	·132	·362	·560	·023
June 6	·380	·658	·007	·326	·561	·777	·222
16	·179	·257	·601	·520	·761	·994	·422
26	·977	·856	·196	·714	·960	·210	·621
July 6	·776	·455	·791	·907	·159	·427	·821
16	·575	·054	·385	·101	·359	·644	·021
26	·373	·653	·980	·295	·558	·861	·220
Aug. 5	·172	·252	·575	·489	·757	·077	·420
15	·970	·851	·169	·683	·957	·294	·619
25	·769	·450	·764	·876	·156	·511	·819
Sept. 4	·567	·049	·359	·070	·356	·728	·018
14	·366	·648	·953	·264	·555	·945	·218
24	·164	·247	·548	·458	·754	·161	·417
Oct. 4	·963	·846	·142	·651	·954	·378	·617
14	·761	·445	·737	·845	·153	·595	·816
24	·560	·044	·332	·039	·352	·812	·016
Nov. 3	·358	·643	·926	·233	·552	·028	·215
13	·157	·242	·521	·427	·751	·245	·415
23	·955	·841	·116	·621	·951	·462	·614
Dec. 3	·754	·440	·710	·814	·150	·679	·814
13	·552	·039	·305	·008	·349	·895	·013
23	·351	·638	·899	·202	·549	·112	·213
1892.							
Jan. 2	·149	·237	·494	·395	·748	·329	·412
12	·948	·836	·089	·589	·947	·546	·612
22	·746	·435	·683	·783	·147	·763	·811
Feb. 1	·545	·034	·278	·977	·346	·979	·011
11	·343	·633	·873	·170	·545	·196	·210

		Inclination. γ_4	Node. $\Omega-\Gamma_4$
		°	°
1891 Sept.	14	0·3468	29·22
Oct.	14	·3471	29·23
Nov.	13	·3474	29·23
Dec.	13	·3476	29·23
1892 Jan.	12	·3479	29·22
Feb.	11	0·3481	29·20

First Satellite.—Motions of

d	h	l_1-0 °	α_1	β_1	γ_1	δ_1	ϵ_1
0	0	0·0	·0000	·000	·000	·000	·000
	6	50·8722	·1418	·035	·141	·141	1
	12	101·7445	·2837	·071	·282	·283	1
	18	152·6167	·4255	·106	·424	·424	2
1	0	203·4890	·5673	·142	·565	·565	·002
	6	254·3618	·7091	·177	·706	·707	3
	12	305·2334	·8510	·213	·847	·848	4
	18	356·1057	·9928	·248	·988	·989	4
2	0	46·9779	·1346	·284	·130	·130	·005
	6	97·8502	·2764	·319	·271	·272	6
	12	148·7224	·4183	·355	·412	·413	6
	18	199·5946	·5601	·390	·553	·554	7
3	0	250·4669	·7019	·425	·694	·696	·007
	6	301·3391	·8437	·461	·836	·837	8
	12	352·2113	·9856	·496	·977	·978	9
	18	43·0836	·1274	·532	·118	·120	9
4	0	93·9558	·2692	·567	·259	·261	·010
	6	144·8281	·4110	·603	·401	·402	·010
	12	195·7003	·5529	·638	·542	·544	·011
	18	246·5725	·6947	·674	·683	·685	·012
5	0	297·4448	·8365	·709	·824	·826	·012
	6	348·3170	·9783	·745	·965	·967	·013
	12	39·1893	·1202	·780	·107	·109	·014
	18	90·0615	·2620	·815	·248	·250	·014
6	0	140·9337	·4038	·851	·389	·391	·015
	6	191·8060	·5456	·886	·530	·533	·015
	12	242·6782	·6875	·922	·671	·674	·016
	18	293·5505	·8293	·957	·813	·815	·017
7	0	344·4227	·9711	·993	·954	·957	·017
	6	35·2949	·1129	·028	·095	·098	·018
	12	86·1672	·2548	·064	·236	·239	·019
	18	137·0394	·3966	·099	·377	·381	·019
8	0	187·9116	·5384	·135	·519	·522	·020
	6	238·7839	·6802	·170	·660	·663	·020
	12	289·6561	·8221	·206	·801	·804	·021
	18	340·5284	·9639	·241	·942	·946	·022
9	0	31·4006	·1057	·276	·083	·087	·022
	6	82·2728	·2475	·312	·225	·228	·023
	12	133·1451	·3894	·347	·366	·370	·023
	18	184·0173	·5312	·383	·507	·511	·024
10	0	234·8896	·6730	·418	·648	·652	·025

Longitude and of Arguments.

		ζ_1	η_1	θ_1			l_1-0	α_1	β_1	γ_1, δ_1
d	h				h	m	°			
0	0	·000	·000	·000	0	0	0·0	·0000	·000	·000
	6	1	1	1		2	0·2826	·0008	0	1
	12	1	1	1		4	0·5652	·0016	0	2
	18	2	2	2		6	0·8479	·0024	1	2
1	0	·002	·002	·002		8	1·1305	·0032	1	3
	6	3	3	3	0	10	1·4131	·0039	·001	·004
	12	3	3	3		20	2·8262	·0079	2	·008
	18	4	4	4		30	4·2394	·0118	3	·012
2	0	·004	·004	·004		40	5·6525	·0158	4	·016
	6	5	5	5		50	7·0656	·0197	5	·020
	12	5	5	5	1	0	8·4787	·0236	·006	·024
	18	6	6	6		10	9·8918	·0276	7	·027
3	0	·007	·006	·006		20	11·3050	·0315	8	·031
	6	7	7	7		30	12·7181	·0355	9	·035
	12	8	7	7		40	14·1312	·0394	·010	·039
	18	8	8	8		50	15·5443	·0433	·011	·043
4	0	·009	·008	·008	2	0	16·9574	·0473	·012	·047
	6	·009	·009	·009		10	18·3705	·0512	·013	·051
	12	·010	·009	·009		20	19·7837	·0552	·014	·055
	18	·010	·010	·010		30	21·1968	·0591	·015	·059
5	0	·011	·010	·010		40	22·6099	·0630	·016	·063
	6	·011	·011	·011		50	24·0230	·0670	·017	·067
	12	·012	·011	·011	3	0	25·4361	·0709	·018	·071
	18	·013	·012	·012		10	26·8492	·0749	·019	·075
6	0	·013	·012	·012		20	28·2624	·0788	·020	·078
	6	·014	·013	·013		30	29·6755	·0827	·021	·082
	12	·014	·013	·013		40	31·0886	·0867	·022	·086
	18	·015	·014	·014		50	32·5017	·0906	·023	·090
7	0	·015	·015	·014	4	0	33·9148	·0946	·024	·094
	6	·016	·015	·015		10	35·3279	·0985	·025	·098
	12	·016	·016	·015		20	36·7411	·1024	·026	·102
	18	·017	·016	·016		30	38·1542	·1064	·027	·106
8	0	·017	·017	·016		40	39·5673	·1103	·028	·110
	6	·018	·017	·017		50	40·9804	·1142	·029	·114
	12	·018	·018	·018	5	0	42·3935	·1182	·030	·118
	18	·019	·018	·018		10	43·8067	·1221	·031	·122
9	0	·020	·019	·019		20	45·2198	·1261	·032	·126
	6	·020	·019	·019		30	46·6329	·1300	·033	·129
	12	·021	·020	·020		40	48·0460	·1339	·033	·133
	18	·021	·020	·020		50	49·4591	·1379	·034	·137
10	0	·022	·021	·021	6	0	50·8722	·1418	·035	·141

First Satellite.—Inequalities.

Arg.	Radius Vector. α_1		β_1	γ_1	δ_1	Longitude. α_1		β_1	Arg.
						°		°	
·000	0·996 152	8	024	000	000	± ·0000	273	± ·0000	·000
·010	6 160	22	24	0	0	·0273	272	01	·990
·020	6 182	38	24	0	0	·0545	269	02	·980
·030	6 220	52	24	0	0	·0814	267	03	·970
·040	6 272	67	23	1	1	·1081	262	05	·960
·050	0·996 339	82	·023	001	001	± ·1343	256	± ·0006	·950
·060	6 421	95	22	2	1	·1599	251	08	·940
·070	6 516	109	21	2	2	·1850	242	10	·930
·080	6 625	122	21	3	2	·2092	235	12	·920
·090	6 747	134	21	3	3	·2327	225	14	·910
·100	0·996 881	147	020	004	004	± ·2552	215	± ·0016	·900
·110	7 028	159	20	5	4	·2767	203	18	·890
·120	7 187	169	21	6	5	·2970	192	22	·880
·130	7 356	179	21	7	6	·3162	179	24	·870
·140	7 535	189	22	8	7	·3341	166	25	·860
·150	0·997 724	198	023	009	008	± ·3507	152	± ·0027	·850
·160	7 922	205	25	10	09	·3659	137	29	·840
·170	8 127	212	27	11	10	·3796	123	30	·830
·180	8 339	219	29	12	11	·3919	106	31	·820
·190	8 458	224	31	13	12	·4025	91	31	·810
·200	0·998 782	229	034	015	014	± ·4116	74	± ·0030	·800
·210	9 011	232	36	16	15	·4190	57	29	·790
·220	9 243	235	39	17	16	·4247	41	27	·780
·230	9 478	236	42	19	17	·4288	24	25	·770
·240	9 714	237	44	20	18	·4312	7	21	·760
·250	0·999 951	237	047	021	020	± ·4319	10	± ·0017	·750
·260	1·000 188	236	49	23	21	·4309	28	13	·740
·270	0 424	234	51	24	22	·4281	44	08	·730
·280	0 658	231	52	25	23	·4237	61	± ·0002	·720
·290	0 889	227	53	27	24	·4176	77	∓ ·0004	·710
·300	1·001 116	222	053	028	026	± ·4099	93	∓ ·0010	·700
·310	1 328	216	53	29	27	·4006	109	∓ 16	·690
·320	1 554	210	52	30	28	·3897	124	∓ 22	·680
·330	1 764	203	51	32	29	·3773	139	∓ 28	·670
·340	1 967	195	49	33	30	·3634	153	∓ 33	·660
·350	1·002 162	186	046	034	031	± ·3481	167	∓ ·0038	·650
·360	2 348	176	43	35	32	·3314	180	∓ 42	·640
·370	2 524	166	40	36	33	·3134	192	∓ 46	·630
·380	2 690	156	36	37	34	·2942	203	∓ 48	·620
·390	2 846	144	32	38	35	·2739	214	∓ 49	·610
·400	1·002 990		028	039	035	± ·2525		∓ ·0049	·600

First Satellite.—Inequalities.

Arg.	Radius Vector. α_1		β_1	γ_1	δ_1	Longitude. α_1		β_1	Arg.
·400	1·002 990	132	028	039	035	± °·2525	224	∓ °·0049	·600
·410	3 122	119	24	39	36	·2301	232	∓ 48	·590
·420	3 241	107	19	40	37	·2069	241	∓ 46	·580
·430	3 348	93	15	41	37	·1828	248	∓ 43	·570
·440	3 441	79	12	41	38	·1580	254	∓ 39	·560
·450	1·003 520	65	008	042	038	± ·1326	259	∓ ·0034	·550
·460	3 585	51	5	42	39	·1067	263	∓ 28	·540
·470	3 636	37	3	42	39	·0804	266	∓ 22	·530
·480	3 673	22	1	42	39	·0538	269	∓ 15	·520
·490	3 695	7	0	43	39	·0269	269	∓ 08	·510
·500	1·003 702		000	043	039	± ·0000		∓ ·0000	·500

Longitude (continued).

Arg.		γ_1	δ_1	ϵ_1	ζ_1	η_1	θ_1	Arg.	
·000	·500	± °·0000	± 00	± 00	± 00	± 00	± 00	·500	·000
·010	·490	02	01	02	04	03	02	·510	·990
·020	·480	03	03	04	08	07	04	·520	·980
·030	·470	05	04	06	12	10	05	·530	·970
·040	·460	06	06	08	16	14	07	·540	·960
·050	·450	± ·0008	± 07	± 09	± 20	± 17	± 09	·550	·950
·060	·440	09	08	11	24	20	10	·560	·940
·070	·430	10	10	13	27	23	12	·570	·930
·080	·420	12	11	15	31	26	14	·580	·920
·090	·410	13	12	16	34	29	15	·590	·910
·100	·400	± ·0014	± 13	± 18	± 38	± 32	± 17	·600	·900
·110	·390	16	14	19	41	35	18	·610	·890
·120	·380	17	15	21	44	37	19	·620	·880
·130	·370	18	16	22	47	40	21	·630	·870
·140	·360	19	17	24	49	42	22	·640	·860
·150	·350	± ·0020	± 18	± 25	± 52	± 44	± 23	·650	·850
·160	·340	21	19	26	54	46	24	·660	·840
·170	·330	21	20	27	56	48	25	·670	·830
·180	·320	22	20	28	58	49	26	·680	·820
·190	·310	23	21	28	60	51	26	·690	·810
·200	·300	± ·0023	± 22	± 29	± 61	± 52	± 27	·700	·800
·210	·290	24	22	30	62	53	27	·710	·790
·220	·280	24	22	30	63	54	28	·720	·780
·230	·270	24	22	30	63	54	28	·730	·770
·240	·260	24	23	30	64	55	28	·740	·760
·250	·250	± ·0024	± 23	± 31	± 64	± 55	± 28	·750	·750

Second Satellite.—Motions of

d	h	l_2-0	α_2	β_2	$\gamma_2, \delta_2, \epsilon_2$	ι_2	κ_2, λ_2
0	0	0·0	·00000	·000	·000	·000	·000
	6	25·3437	·07091	·035	·070	1	·071
	12	50·6874	·14183	·071	·141	1	·143
	18	76·0310	·21274	·106	·211	2	·214
1	0	101·3747	·28365	·142	·282	·002	·286
	6	126·7184	·35456	·177	·352	3	·357
	12	152·0621	·42548	·213	·422	4	·429
	18	177·4058	·49639	·248	·493	4	·500
2	0	202·7495	·56730	·284	·563	·005	·571
	6	228·0931	·63821	·319	·634	6	·643
	12	253·4368	·70913	·355	·704	6	·714
	18	278·7805	·78004	·390	·774	7	·786
3	0	304·1242	·85095	·425	·845	·007	·857
	6	329·4679	·92186	·461	·915	8	·929
	12	354·8115	·99278	·496	·986	9	·000
	18	20·1552	·06369	·532	·056	9	·071
4	0	45·4989	·13460	·567	·126	·010	·143
	6	70·8426	·20552	·603	·197	·010	·214
	12	96·1863	·27643	·638	·267	·011	·286
	18	121·5299	·34734	·674	·337	·012	·357
5	0	146·8736	·41825	·709	·408	·012	·429
	6	172·2173	·48917	·745	·478	·013	·500
	12	197·5610	·56008	·780	·549	·014	·571
	18	222·9047	·63099	·815	·619	·014	·643
6	0	248·2484	·70190	·851	·689	·015	·714
	6	273·5920	·77282	·886	·760	·015	·786
	12	298·9357	·84373	·922	·830	·016	·857
	18	324·2794	·91464	·957	·901	·017	·929
7	0	349·6231	·98555	·993	·971	·017	·000
	6	14·9668	·05647	·028	·041	·018	·072
	12	40·3104	·12738	·064	·112	·019	·143
	18	65·6541	·19829	·099	·182	·019	·214
8	0	90·9978	·26921	·135	·253	·020	·286
	6	116·3415	·34012	·170	·323	·020	·357
	12	141·6852	·41103	·206	·393	·021	·429
	18	167·0288	·48194	·241	·464	·021	·500
9	0	192·3725	·55286	·276	·534	·022	·572
	6	217·7162	·62377	·312	·605	·023	·643
	12	243·0599	·69468	·347	·675	·023	·714
	18	268·4036	·76559	·383	·745	·024	·786
10	0	293·7473	·83651	·418	·816	·025	·857

The motions of ζ_2, η_2, θ_2 are the same as those of ζ η, θ on p. 525.

Longitude and of Arguments.

h	m	$l_2 - 0$	α_2	β_2	$\gamma_2, \delta_2, \epsilon_2$	κ_2, λ_2
		°				
0	0	0·0000	·00000	·000	·000	·000
	2	0·1408	·00039	0	0	0
	4	0·2816	·00079	0	1	1
	6	0·4224	·00118	1	1	1
	8	0·5632	·00148	1	2	2
0	10	0·7040	·00197	·001	·002	·002
	20	1·4080	·00394	2	4	4
	30	2·1120	·00591	3	6	6
	40	2·8160	·00788	4	8	8
	50	3·5200	·00985	5	·010	·010
1	0	4·2239	·01182	·006	·012	·012
	10	4·9279	·01379	·007	·014	·014
	20	5·6319	·01576	·008	·016	·016
	30	6·3359	·01773	·009	·018	·018
	40	7·0399	·01970	·010	·020	·020
	50	7·7439	·02167	·011	·022	·022
2	0	8·4479	·02364	·012	·023	·024
	10	9·1519	·02561	·013	·025	·026
	20	9·8559	·02758	·014	·027	·028
	30	10·5599	·02955	·015	·029	·030
	40	11·2639	·03152	·016	·031	·032
	50	11·9678	·03349	·017	·033	·034
3	0	12·6718	·03546	·018	·035	·036
	10	13·3758	·03743	·019	·037	·038
	20	14·0798	·03940	·020	·039	·040
	30	14·7838	·04137	·021	·041	·042
	40	15·4878	·04334	·022	·043	·044
	50	16·1918	·04531	·023	·045	·046
4	0	16·8958	·04728	·024	·047	·048
	10	17·5998	·04924	·025	·049	·050
	20	18·3038	·05121	·026	·051	·052
	30	19·0078	·05318	·027	·053	·054
	40	19·7118	·05515	·028	·055	·056
	50	20·4157	·05712	·029	·057	·058
5	0	21·1197	·05909	·030	·059	·060
	10	21·8237	·06106	·031	·061	·062
	20	22·5277	·06303	·032	·063	·063
	30	23·2317	·06500	·033	·065	·065
	40	23·9357	·06697	·033	·066	·067
	50	24·6397	·06894	·034	·068	·069
6	0	25·3437	·07091	·035	·070	·071

Second Satellite.—Inequalities.

Arg.	Radius Vector. α_2		β_2	γ_2	δ_2	ϵ_2	κ_2	λ_2	Longitude. α_3 °		Arg.
·000	0·990 487	18	079	000	000	000	000	000	± 0·0000	653	·000
·010	0 505	54	79	00	00	00	0	0	·0653	650	·990
·020	0 559	90	77	01	02	01	0	0	·1303	644	·980
·030	0 649	125	75	02	03	02	0	0	·1947	637	·970
·040	0 774	160	72	03	06	03	0	0	·2584	626	·960
·050	0·990 934	195	068	005	009	005	001	000	± 0·3210	613	·950
·060	1 129	218	63	07	13	07	1	1	·3823	597	·940
·070	1 357	260	58	10	18	10	1	1	·4420	579	·930
·080	1 617	292	52	14	24	13	2	1	·4999	558	·920
·090	1 909	322	46	17	30	16	2	1	·5557	536	·910
·100	0·992 231	352	040	021	037	020	003	001	± 0·6093	511	·900
·110	2 583	379	34	25	44	24	3	2	·6604	484	·890
·120	2 962	405	28	30	52	28	4	2	·7088	455	·880
·130	3 367	429	22	35	61	33	5	2	·7543	424	·870
·140	3 796	453	17	40	70	38	6	3	·7967	393	·860
·150	0·994 249	473	012	045	080	043	006	003	± 0·8360	358	·850
·160	4 722	492	08	51	090	48	07	4	·8718	324	·840
·170	5 214	509	05	57	100	53	08	4	·9042	287	·830
·180	5 723	524	02	63	111	59	09	5	·9329	250	·820
·190	6 247	537	01	69	122	65	10	5	·9579	211	·810
·200	0·996 784	547	000	076	133	071	011	005	± 0·9790	173	·800
·210	7 331	556	01	82	145	77	11	6	0·9963	133	·790
·220	7 887	561	02	89	157	84	12	6	1·0096	93	·780
·230	8 448	566	05	096	169	90	13	7	1·0189	53	·770
·240	9 014	568	09	103	181	097	14	7	1·0242	12	·760
·250	0·999 582	566	014	110	193	103	015	008	± 1·0254	28	·750
·260	1·000 148	564	19	116	205	110	16	08	1·0226	68	·740
·270	0 712	558	26	123	217	116	17	09	1·0158	108	·730
·280	1 270	551	34	130	229	123	18	09	1·0050	147	·720
·290	1 821	541	42	137	241	129	19	10	0·9903	186	·710
·300	1·002 362	529	051	143	253	135	020	010	± 0·9717	224	·700
·310	2 891	516	61	150	264	141	21	11	·0493	260	·690
·320	3 407	500	71	156	275	147	22	11	·9233	296	·680
·330	3 907	482	81	162	286	153	23	12	·8937	331	·670
·340	4 389	463	092	168	297	159	23	12	·8606	365	·660
·350	1·004 852	441	103	174	307	164	024	013	± 0·8241	396	·650
·360	5 293	418	113	179	316	169	25	13	·7845	427	·640
·370	5 711	394	124	185	325	174	26	13	·7418	455	·630
·380	6 105	368	134	190	334	178	27	14	·6963	482	·620
·390	6 473	340	144	194	342	183	27	14	·6481	507	·610
·400	1·006 813		153	198	349	187	028	014	± 0·5974		·600

Second Satellite.—Inequalities.

Arg.	Radius Vector. α_2		β_2	γ_2	δ_2	ϵ_2	κ_2	λ_2	Longitude. α_2		Arg.
·400	1·006 813		153	198	349	187	028	014	± 0·5974		·600
		311								530	
·410	7 124		161	202	356	190	28	15	·5444		·590
		282								551	
·420	7 406		169	206	362	194	29	15	·4893		·580
		252								569	
·430	7 658		177	209	368	197	29	15	·4324		·570
		219								587	
·440	7 877		183	212	373	199	29	15	·3737		·560
		187								600	
·450	1·008 064		189	214	377	201	030	015	± 0·3137		·550
		154								613	
·460	8 218		193	216	380	203	30	16	·2524		·540
		120								623	
·470	8 338		197	217	383	205	30	16	·1901		·530
		87								629	
·480	8 425		199	218	385	206	30	16	·1272		·520
		52								635	
·490	8 477		201	219	386	206	30	16	·0637		·510
		17								637	
·500	1·008494		202	219	386	206	030	016	± 0·0000		·500

Longitude (*continued*).

Arg.		β_2	γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2	Arg.	
·00	·50	∓ ·0000	± ·0000	·0000	·0000	·0000	·0000	·0000	00	00	00	·50	·00
·01	·49	∓ 03	08	14	07	17	21	11	01	01	01	·51	·99
·02	·48	∓ 06	16	28	15	33	42	22	02	02	01	·52	·98
·03	·47	∓ 09	24	41	22	50	63	33	03	04	02	·53	·97
·04	·46	∓ 09	31	55	29	66	83	44	05	05	03	·54	·96
·05	·45	∓ ·0009	∓ ·0039	·0068	·0037	·0082	·0104	·0054	06	06	03	·55	·95
·06	·44	∓ 06	46	·0081	44	·0097	·0123	64	07	07	04	·56	·94
·07	·43	∓ 01	54	·0094	50	·0113	·0142	74	08	08	04	·57	·93
·08	·42	± 06	61	·0107	57	·0128	·0161	84	09	09	05	·58	·92
·09	·41	± 15	67	·0119	63	·0142	·0180	94	10	10	05	·59	·91
·10	·40	± ·0025	± ·0074	·0130	·0069	·0156	·0197	·0103	11	11	06	·60	·90
·11	·39	37	80	·0141	75	·0169	·0214	·0111	12	12	06	·61	·89
·12	·38	51	86	·0152	81	·0181	·0229	·0120	13	13	07	·62	·88
·13	·37	65	92	·0161	86	·0193	·0244	·0128	13	14	07	·63	·87
·14	·36	81	97	·0171	91	·0204	·0258	·0135	14	15	08	·64	·86
·15	·35	± ·0096	± ·0102	·0179	·0096	·0214	·0271	·0142	15	16	08	·65	·85
·16	·34	·0111	·0106	·0187	·0100	·0223	·0283	·0148	16	16	08	·66	·84
·17	·33	·0125	·0110	·0194	·0104	·0232	·0294	·0153	16	17	09	·67	·83
·18	·32	·0139	·0114	·0200	·0107	·0239	·0303	·0158	17	17	09	·68	·82
·19	·31	·0151	·0117	·0206	·0110	·0246	·0312	·0163	17	18	09	·69	·81
·20	·30	± ·0162	± ·0120	·0211	·0113	·0252	·0319	·0166	17	18	10	·70	·80
·21	·29	·0171	·0122	·0214	·0115	·0256	·0325	·0169	18	19	10	·71	·79
·22	·28	·0178	·0123	·0217	·0116	·0260	·0329	·0172	18	19	10	·72	·78
·23	·27	·0183	·0125	·0220	·0117	·0263	·0333	·0174	18	19	10	·73	·77
·24	·26	·0187	·0125	·0221	·0118	·0264	·0335	·0175	18	19	10	·74	·76
·25	·25	± ·0188	± ·0126	·0221	·0118	·0265	·0335	·0175	18	19	10	·75	·75

Third Satellite.—Motions of

d	h	l_3-0	α_3, β_3	γ_3	δ_3	e_3	ι_3
		°					
0	0	0·0	·0000	·0000	·000	·000	·000
	6	12·5794	·0349	·0355	·020	·036	·035
	12	25·1588	·0699	·0709	·040	·072	·070
	18	37·7382	·1048	·1064	·060	·108	·105
1	0	50·3196	·1398	·1418	·080	·144	·140
	6	62·8970	·1747	·1773	·100	·180	·175
	12	75·4764	·2096	·2127	·120	·216	·209
	18	88·0558	·2446	·2482	·140	·252	·244
2	0	100·6352	·2795	·2837	·160	·288	·279
	6	113·2146	·3144	·3191	·180	·324	·314
	12	125·7940	·3494	·3546	·200	·360	·349
	18	138·3734	·3843	·3900	·220	·396	·384
3	0	150·9528	·4192	·4255	·240	·432	·419
	6	163·5322	·4542	·4609	·259	·468	·454
	12	176·1116	·4891	·4964	·279	·504	·489
	18	188·6910	·5241	·5318	·299	·540	·524
4	0	201·2704	·5590	·5673	·319	·576	·559
	6	213·8498	·5939	·6028	·339	·611	·594
	12	226·4292	·6289	·6382	·359	·647	·628
	18	239·0086	·6638	·6737	·379	·683	·663
5	0	251·5881	·6988	·7091	·399	·719	·698
	6	264·1675	·7337	·7446	·419	·755	·733
	12	276·7469	·7686	·7800	·439	·791	·768
	18	289·3263	·8036	·8155	·459	·827	·803
6	0	301·9057	·8385	·8510	·479	·863	·838
	6	314·4851	·8734	·8864	·499	·899	·873
	12	327·0645	·9083	·9217	·519	·935	·908
	18	339·6439	·9433	·9573	·539	·971	·943
7	0	352·2233	·9783	·9928	·559	·007	·978
	6	4·8027	·0132	·0282	·579	·043	·012
	12	17·3821	·0481	·0637	·599	·079	·047
	18	29·9615	·0831	·0991	·619	·115	·082
8	0	42·5409	·1180	·1346	·639	·151	·117
	6	55·1203	·1530	·1701	·659	·187	·152
	12	67·6997	·1879	·2055	·679	·223	·187
	18	80·2791	·2228	·2410	·699	·259	·222
9	0	92·8585	·2578	·2764	·719	·295	·257
	6	105·4379	·2927	·3119	·739	·331	·292
	12	118·0173	·3276	·3473	·759	·367	·327
	18	130·5967	·3626	·3828	·779	·403	·362
10	0	143·1761	·3975	·4183	·799	·439	·397

The motions of ζ_3, γ_3, θ_3 are the same as those of ζ, γ, β on p. 525.

Longitude and of Arguments.

		$l_3 - 0$	α_3, β_3	γ_3	δ_3	ϵ_3	ι_3
h	m	°					
0	0	0·0	·0000	·0000	·000	·000	·000
	2	0·0699	02	02	0	0	0
	4	0·1398	04	04	0	0	0
	6	0·2097	06	06	0	1	1
	8	0·2795	08	08	0	1	1
0	10	0·3494	·0010	·0010	·001	·001	·001
	20	0·6989	19	20	1	2	2
	30	1·0483	29	30	2	3	3
	40	1·3977	39	39	2	4	4
	50	1·7471	49	49	3	5	5
1	0	2·0966	·0058	·0059	·003	·006	·006
	10	2·4460	·0068	·0069	4	7	7
	20	2·7954	·0078	·0079	4	8	8
	30	3·1449	·0087	·0089	5	9	9
	40	3·4943	·0097	·0098	6	·010	·010
	50	3·8437	·0107	·0108	6	·011	·011
2	0	4·1931	·0116	·0118	·007	·012	·012
	10	4·5426	·0126	·0128	7	·013	·013
	20	4·8920	·0136	·0138	8	·014	·014
	30	5·2414	·0146	·0147	8	·015	·015
	40	5·5908	·0155	·0157	9	·016	·016
	50	5·9403	·0165	·0167	9	·017	·016
3	0	6·2897	·0175	·0177	·010	·018	·017
	10	6·6391	·0184	·0187	·011	·019	·018
	20	6·9886	·0194	·0197	·011	·020	·019
	30	7·3380	·0204	·0207	·012	·021	·020
	40	7·6874	·0214	·0217	·012	·022	·021
	50	8·0368	·0223	·0227	·013	·023	·022
4	0	8·3863	·0233	·0236	·013	·024	·023
	10	8·7357	·0243	·0246	·014	·025	·024
	20	9·0851	·0252	·0256	·014	·026	·025
	30	9·4346	·0262	·0266	·015	·027	·026
	40	9·7840	·0272	·0276	·016	·028	·027
	50	10·1334	·0281	·0286	·016	·029	·028
5	0	10·4828	·0291	·0295	·017	·030	·029
	10	10·8323	·0301	·0305	·017	·031	·030
	20	11·1817	·0311	·0315	·018	·032	·031
	30	11·5311	·0320	·0325	·018	·033	·032
	40	11·8805	·0330	·0335	·019	·034	·033
	50	12·2300	·0340	·0345	·019	·035	·034
6	0	12·5794	·0349	·0355	·020	·036	·035

Third Satellite.—Inequalities.

Arg.	a_3		Radius Vector. β_3	γ_3	δ_3	ϵ_3, ι_3	Longitude. γ_3		δ_3	Arg.
·000	0·997 573	2	0000	0000	000	0	± °·0000	39	± °·0000	·000
·010	7 575	7	01	01	01	0	039	39	18	·990
·020	7 582	11	05	04	04	0	078	39	36	·980
·030	7 593	15	11	08	08	0	117	39	54	·970
·040	7 608	20	19	15	15	0	156	37	71	·960
·050	0·997 628	24	0029	0024	023	0	± ·0193	37	± ·0087	·950
·060	7 652	28	41	34	32	1	230	36	102	·940
·070	7 680	32	56	46	43	1	266	35	116	·930
·080	7 712	36	73	61	55	1	301	34	128	·920
·090	7 748	40	92	76	69	1	325	32	139	·910
·100	0·997 788	43	0113	0095	084	1	± ·0367	31	± ·0147	·900
·110	7 831	47	135	115	099	1	398	30	154	·890
·120	7 878	50	160	137	115	1	428	27	159	·880
·130	7 928	53	186	160	131	2	455	26	162	·870
·140	7 981	56	214	186	147	2	481	24	162	·860
·150	0·998 037	58	0243	0213	164	2	± ·0505	22	± ·0161	·850
·160	8 095	61	273	241	180	2	527	20	157	·840
·170	8 156	63	305	271	195	3	547	18	151	·830
·180	8 219	65	338	303	209	3	565	16	144	·820
·190	8 284	66	372	336	223	3	581	13	134	·810
·200	0·998 350	68	0407	0369	235	3	± ·0594	12	± ·0123	·800
·210	8 418	69	442	404	246	4	606	9	111	·790
·220	8 487	69	478	440	255	4	615	7	097	·780
·230	8 556	70	514	476	263	4	622	4	082	·770
·240	8 626	71	551	512	269	5	626	3	066	·760
·250	0·998 697	70	0588	0549	273	5	± ·0629	0	± ·0050	·750
·260	8 767	70	625	587	276	5	629	2	± 33	·740
·270	8 837	70	661	624	276	6	627	5	± 16	·730
·280	8 907	69	698	661	274	6	622	7	∓ 02	·720
·290	8 976	67	734	697	271	6	615	9	∓ 18	·710
·300	0·999 043	67	0769	0733	265	7	± ·0606	11	∓ ·0035	·700
·310	9 110	64	804	769	258	7	595	14	∓ 50	·690
·320	9 174	63	837	804	249	7	581	16	∓ 65	·680
·330	9 237	61	870	838	238	7	565	19	∓ 78	·670
·340	9 298	58	902	871	226	8	546	20	∓ 89	·660
·350	0·999 356	55	0932	0902	212	8	± ·0526	23	∓ ·0099	·650
·360	9 411	53	0961	0933	197	8	503	25	∓ 108	·640
·370	9 464	50	0989	0962	181	8	478	28	∓ 114	·630
·380	9 514	46	1015	0989	164	9	450	29	∓ 117	·620
·390	9 560	43	1039	1015	146	9	421	31	∓ 119	·610
·400	0·999 603		1061	1039	129	9	± ·0390		∓ ·0118	·600

Third Satellite.—Inequalities.

Arg.	Radius Vector. α_3		β_3	γ_3	δ_3	ϵ_3, ι_3	Longitude. γ_3		δ_3	Arg.
·400	0·999 603	40	1061	1039	129	09	± ·0390	33	∓ ·0118	·600
·410	9 643	35	1082	1062	111	09	357	35	∓ 115	·590
·420	9 678	32	1101	1082	095	09	322	37	∓ 109	·580
·430	9 710	28	1117	1100	079	10	285	38	∓ 101	·570
·440	9 738	24	1132	1116	064	10	247	39	∓ 091	·560
·450	0·999 762	20	1144	1129	051	10	± ·0208	40	∓ ·0079	·550
·460	9 782	15	1154	1140	040	10	168	41	∓ 66	·540
·470	9 797	11	1162	1149	031	10	127	42	∓ 51	·530
·480	9 808	7	1168	1155	024	10	085	42	∓ 34	·520
·490	9 815	2	1172	1159	020	10	043	43	∓ 17	·510
·500	0·999 817		1173	1161	019	10	± ·0000		∓ ·0000	·500

Longitude (continued).

Arg.		α_3		β_3		ζ_3	η_3	θ_3	ϵ_3, ι_3	Arg.	
·000	·500	± ·0000	81	± ·0000	42	± ·0000	00	00	0	·500	·000
·010	·490	081	80	042	42	03	04	02	0	·510	·990
·020	·480	161	80	084	42	06	08	04	0	·520	·980
·030	·470	241	79	126	41	08	12	06	1	·530	·970
·040	·460	320	77	167	41	11	16	08	1	·540	·960
·050	·450	± ·0397	76	± ·0208	39	± ·0014	20	10	2	·550	·950
·060	·440	473	74	247	39	16	24	12	2	·560	·940
·070	·430	547	72	286	38	19	28	14	2	·570	·930
·080	·420	619	70	324	36	21	32	16	3	·580	·920
·090	·410	689	67	360	35	24	35	18	3	·590	·910
·100	·400	± ·0756	64	± ·0395	33	± ·0026	39	20	3	·600	·900
·110	·390	820	60	428	32	28	42	21	4	·610	·890
·120	·380	880	57	460	30	30	45	23	4	·620	·880
·130	·370	937	54	490	28	32	48	24	4	·630	·870
·140	·360	·0991	49	518	26	34	51	26	4	·640	·860
·150	·350	± ·1040	46	± ·0544	23	± ·0036	53	27	5	·650	·850
·160	·340	·1086	41	567	22	37	55	28	5	·660	·840
·170	·330	·1127	36	589	19	38	57	29	5	·670	·830
·180	·320	·1163	32	608	17	40	59	30	5	·680	·820
·190	·310	·1195	28	625	14	41	61	31	5	·690	·810
·200	·300	± ·1223	22	± ·0639	12	± ·0042	62	32	5	·700	·800
·210	·290	·1245	18	651	9	43	64	32	5	·710	·790
·220	·280	·1263	13	660	7	43	64	33	5	·720	·780
·230	·270	·1276	7	667	4	44	65	33	6	·730	·770
·240	·260	·1283	3	671		44	65	33	6	·740	·760
·250	·250	± ·1286		± ·0672		± ·0044	66	34	06	·750	·750

Fourth Satellite.—Motions of

d	h	l_4-0	α_4	β_4	$\gamma_\omega\ \delta_4$	ϵ_4	$\zeta_4,\ \theta_4$	η_4
		°						
0	0	0·0	·000 00	·000	·000	·000	·000	·000
	6	5·3928	·014 98	·020	·015	·030	·005	·055
	12	10·7855	·029 96	·040	·030	·060	·010	·111
	18	16·1783	·044 94	·060	·045	·090	·015	·166
1	0	21·5711	·059 91	·080	·060	·119	·020	·222
	6	26·9638	·074 89	·100	·075	·149	·025	·277
	12	32·3566	·089 87	·120	·090	·179	·030	·333
	18	37·7494	·104 85	·140	·105	·209	·035	·388
2	0	43·1421	·119 83	·160	·120	·239	·040	·443
	6	48·5349	·134 81	·180	·135	·269	·045	·499
	12	53·9277	·149 79	·200	·150	·298	·050	·554
	18	59·3205	·164 76	·220	·165	·328	·055	·610
3	0	64·7132	·179 74	·240	·180	·358	·060	·665
	6	70·1060	·194 72	·259	·195	·388	·065	·720
	12	75·4988	·209 70	·279	·210	·418	·070	·776
	18	80·8915	·224 68	·299	·225	·448	·075	·831
4	0	86·2843	·239 66	·319	·240	·478	·080	·887
	6	91·6771	·254 64	·339	·255	·507	·085	·942
	12	97·0698	·269 61	·359	·270	·537	·090	·998
	18	102·4626	·284 59	·379	·285	·567	·095	·053
5	0	107·8554	·299 57	·399	·299	·597	·100	·108
	6	113·2481	·314 55	·419	·314	·627	·105	·164
	12	118·6409	·329 53	·439	·329	·657	·110	·219
	18	124·0337	·344 51	·459	·344	·686	·115	·275
6	0	129·4264	·359 49	·479	·359	·716	·120	·330
	6	134·8192	·374 46	·499	·374	·746	·125	·385
	12	140·2120	·389 44	·519	·389	·776	·130	·441
	18	145·6047	·404 42	·539	·404	·806	·135	·496
7	0	150·9975	·419 40	·559	·419	·836	·140	·552
	6	156·3903	·434 38	·579	·434	·865	·145	·607
	12	161·7831	·449 36	·599	·449	·895	·150	·663
	18	167·1758	·464 33	·619	·464	·925	·155	·718
8	0	172·5686	·479 31	·639	·479	·955	·160	·773
	6	177·9614	·494 29	·659	·494	·985	·165	·829
	12	183·3541	·509 27	·679	·509	·015	·170	·884
	18	188·7469	·524 25	·699	·524	·045	·175	·940
9	0	194·1397	·539 23	·719	·539	·074	·180	·995
	6	199·5324	·554 21	·739	·554	·104	·185	·051
	12	204·9252	·569 18	·759	·569	·134	·190	·106
	18	210·3180	·584 16	·779	·584	·174	·195	·161
10	0	215·7107	·599 14	·799	·599	·194	·200	·217

Longitude and of Arguments.

		$l_4 - 0$	α_4	β_4	γ_4, δ_4	ϵ_4	η_4
h	m	°					
0	0	0·0	·00000	·000	...	·000	·000
	2	0·0300	008	0	...	0	0
	4	0·0599	017	0	...	0	1
	6	0·0899	025	0	...	0	1
	8	0·1198	033	0	...	1	1
0	10	0·1498	·00042	·001	·000	·001	·002
	20	0·2996	083	1	1	2	3
	30	0·4494	125	2	1	2	5
	40	0·5992	166	2	2	3	6
	50	0·7490	208	3	2	4	8
1	0	0·8988	·00250	·003	·002	·005	·009
	10	1·0486	291	4	3	6	·011
	20	1·1984	333	4	3	7	·012
	30	1·3482	374	5	4	7	·014
	40	1·4980	416	6	4	8	·015
	50	1·6478	458	6	5	9	·017
2	0	1·7976	·00499	·007	·005	·010	·018
	10	1·9474	541	7	5	·011	·020
	20	2·0972	582	8	6	·012	·022
	30	2·2470	624		6	·012	·023
	40	2·3968	666	9	7	·013	·025
	50	2·5466	707	9	7	·014	·026
3	0	2·6964	·00749	·010	·007	·015	·028
	10	2·8462	791	·011	·008	·016	·029
	20	2·9960	832	·011	·008	·017	·031
	30	3·1458	874	·012	·009	·017	·032
	40	3·2956	915	·012	·009	·018	·034
	50	3·4454	957	·013	·010	·019	·035
4	0	3·5952	·00999	·013	·010	·020	·037
	10	3·7450	·01040	·014	·010	·021	·038
	20	3·8948	·01082	·014	·011	·022	·040
	30	4·0446	·01123	·015	·011	·022	·042
	40	4·1944	·01165	·016	·012	·023	·043
	50	4·3442	·01207	·016	·012	·024	·045
5	0	4·4940	·01248	·017	·012	·025	·046
	10	4·6438	·01290	·017	·013	·026	·048
	20	4·7936	·01331	·018	·013	·027	·049
	30	4·9434	·01373	·018	·014	·027	·051
	40	5·0932	·01415	·019	·014	·028	·052
	50	5·2430	·01456	·019	·015	·029	·054
6	0	5·3928	·01498	·020	·015	·030	·055

Fourth Satellite.—Inequalities.

Arg.	a_4		Radius Vector. β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	Longitude. α_4		β_4	Arg.
·000	0·992 420	15	000	000	000	0	0	17	± ·0000	527	± 00	·000
·010	2 435	43	0	0	0	0	0	17	·0527	525	01	·990
·020	2 478	72	1	1	0	0	0	17	·1052	521	01	·980
·030	2 550	101	1	2	1	0	0	17	·1573	515	02	·970
·040	2 651	129	2	4	2	0	0	17	·2088	506	02	·960
·050	0·992 780	157	003	007	003	1	0	16	± ·2594	495	± 02	·950
·060	2 937	184	5	10	4	1	0	16	·3089	483	03	·940
·070	3 121	209	7	14	5	1	0	16	·3572	469	04	·930
·080	3 330	235	09	18	7	2	1	16	·4041	452	04	·920
·090	3 565	260	011	22	9	2	1	15	·4493	434	05	·910
·100	0·993 825	283	013	027	011	3	1	15	± ·4927	414	± 05	·900
·110	4 108	304	16	33	13	3	1	15	·5341	393	06	·890
·120	9 412	326	19	39	15	4	1	15	·5734	370	07	·880
·130	4 738	346	22	45	17	5	1	14	·6104	345	08	·870
·140	5 084	363	25	52	20	5	2	14	·6449	319	08	·860
·150	0·995 447	380	028	059	023	6	2	13	± ·6768	292	± 09	·850
·160	5 827	396	32	66	25	7	2	13	·7060	264	10	·840
·170	6 223	409	36	74	28	8	2	12	·7324	235	11	·830
·180	6 632	421	40	82	31	9	2	12	·7559	204	13	·820
·190	7 053	431	44	90	35	9	3	11	·7763	173	14	·810
·200	0·997 484	440	048	099	038	10	3	11	± ·7936	142	± 15	·800
·210	7 924	446	53	107	41	11	3	10	·8078	110	17	·790
·220	8 370	452	58	116	44	12	3	10	·8188	77	18	·780
·230	8 822	454	63	125	48	13	4	9	·8265	45	20	·770
·240	9 276	456	69	134	51	14	4	9	·8310	11	23	·760
·250	0·999 732	456	075	143	055	15	4	8	± ·8321	21	± 23	·750
·260	1·000 188	453	081	152	58	16	5	8	·8300	54	24	·740
·270	0 641	450	088	161	62	17	5	7	·8246	86	26	·730
·280	1 091	444	095	170	65	18	5	7	·8160	118	27	·720
·290	1 535	436	102	179	68	18	5	6	·8042	150	29	·710
·300	1·001 971	427	109	187	072	19	6	6	± ·7892	181	± 30	·700
·310	2 398	416	117	196	75	20	6	5	·7711	211	31	·690
·320	2 814	404	125	204	78	21	6	5	·7500	240	32	·680
·330	3 218	389	133	212	81	22	6	4	·7260	268	33	·670
·340	3 607	374	141	220	84	23	7	4	·6992	296	33	·660
·350	1·003 981	358	149	227	087	24	7	3	± ·6696	322	± 34	·650
·360	4 339	339	158	234	90	24	7	3	·6374	346	33	·640
·370	4 678	319	166	241	92	25	7	3	·6028	369	33	·630
·380	4 997	298	174	247	95	26	7	2	·5659	392	32	·620
·390	5 295	276	182	253	97	26	8	2	·5267	412	31	·610
·400	1·005 571		189	259	099	27	8	2	± ·4855		± 30	·600

Fourth Satellite—Inequalities.

Arg.	Radius Vector. α_4		β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	Longitude. α_4		β_4	Arg.
·400	1·005 571	253	189	259	099	27	8	2	± ·4855	430	± 30	·600
·410	5 824	230	196	264	101	27	8	1	·4425	448	28	·590
·420	6 054	204	203	269	103	28	8	1	·3977	463	26	·580
·430	6 258	179	209	273	104	28	8	1	·3514	477	23	·570
·440	6 437	152	214	276	106	29	8	1	·3037	488	20	·560
·450	1·006 589	126	219	279	107	29	8	0	± ·2549	498	± 17	·550
·460	6 715	98	223	282	108	29	9	0	·2051	506	14	·540
·470	6 813	70	226	284	108	29	9	0	·1545	511	11	·530
·480	6 883	42	229	285	109	29	9	0	·1034	516	07	·520
·490	6 925	14	230	286	109	30	9	0	·0518	518	04	·510
·500	1·006 939		230	286	109	30	9	0	± ·0000		± 00	·500

Longitude (continued).

Arg.		γ_4	δ_4	ϵ_4	ζ_4	η_4, β_4	Arg.	
·000	·500	± ·0000	± ·0000	± 00	± 0	± 0	·500	·000
·010	·490	10	04	01	0	0	·510	·990
·020	·480	21	08	01	1	1	·520	·980
·030	·470	31	12	02	1	1	·530	·970
·040	·460	41	16	03	2	1	·540	·960
·050	·450	± ·0051	± ·0019	± 04	± 2	± 1	·550	·950
·060	·440	61	23	04	3	2	·560	·940
·070	·430	70	27	05	3	2	·570	·930
·080	·420	79	30	06	3	2	·580	·920
·090	·410	88	34	06	4	3	·590	·910
·100	·400	± ·0097	± ·0037	± 07	± 4	± 3	·600	·900
·110	·390	105	40	07	4	3	·610	·890
·120	·380	112	43	08	5	3	·620	·880
·130	·370	119	46	09	5	3	·630	·870
·140	·360	126	48	09	5	4	·640	·860
·150	·350	± ·0133	± ·0051	± 09	± 6	± 4	·650	·850
·160	·340	139	53	10	6	4	·660	·840
·170	·330	144	55	10	6	4	·670	·830
·180	·320	149	57	11	6	4	·680	·820
·190	·310	153	58	11	7	4	·690	·810
·200	·300	± ·0156	± ·0060	± 11	± 7	± 4	·700	·800
·210	·290	159	61	11	7	5	·710	·790
·220	·280	161	61	11	7	5	·720	·780
·230	·270	163	62	12	7	5	·730	·770
·240	·260	164	62	12	7	5	·740	·760
·250	·250	± ·0164	± ·0063	± 12	± 7	± 5	·750	·750

Ephemeris for Physical Observations of the Moon. By A. Marth.
1891, September 10 to October 28.

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat.	Geocentric Libration. Combined Amount.	Direction.
1891.	°	°	°	°	°	°
Sept. 10	355·93	+1·47	−7·06	+0·81	7·11	83·4
11	8·13	1·46	7·60	2·23	7·92	73·6
12	20·33	1·45	7·74	3·58	8·53	65·1
13	32·52	1·45	7·41	4·78	8·81	57·0
14	44·70	1·44	6·57	5·74	8·71	48·7
15	56·88	1·43	5·22	6·37	8·23	39·2
16	69·05	1·42	3·44	6·59	7·43	27·5
17	81·22	1·41	−1·36	6·35	6·50	12·1
18	93·38	1·39	+0·82	5·66	5·72	351·8
19	105·55	1·38	2·92	4·57	5·42	327·5
20	117·72	1·36	4·75	3·17	5·71	303·8
21	129·89	1·35	6·19	+1·60	6·39	284·5
22	142·06	1·33	7·18	−0·03	7·18	269·7
23	154·24	1·31	7·70	1·61	7·86	258·1
24	166·43	1·29	7·78	3·05	8·36	248·5
25	178·63	1·28	7·49	4·30	8·63	240·0
26	190·83	1·26	6·90	5·30	8·69	232·3
27	203·03	1·24	6·06	6·03	8·54	225·0
28	215·24	1·23	5·04	6·48	8·20	217·7
29	227·46	1·21	3·90	6·63	7.69	210·3
30	239·67	+1·19	+2·67	−6·50	7·02	202·2
Oct. 10	1·79	+1·03	−7·34	+4·68	8·70	57·3
11	13·97	1·01	7·10	5·67	9·08	51·2
12	26·15	0·99	6·41	6·37	9·03	45·0
13	38·32	0·97	5·28	6·70	8·53	38·1
14	50·48	0·94	3·75	6·61	7·60	29·4
15	62·64	0·91	−1·91	6·07	6·36	17·4
16	74·79	0·89	+0·10	5·10	5·10	359·9
17	86·94	0·87	2·10	3·77	4·34	330·9
18	99·09	0·84	3·93	2·19	4·50	299·2
19	111·24	0·81	5·46	+0·49	5·48	275·2
20	123·39	0·78	6·58	−1·20	6·68	259·7
21	135·55	0·76	7·26	2·76	7·76	249·1
22	147·71	0·73	7·49	4·13	8·55	241·1

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
1891.	°	°	°	°	°	•
Oct. 23	159·88	0·70	7·32	5·23	8·99	234·3
24	172·06	0·67	6·80	6·04	9·09	228·2
25	184·24	0·65	5·98	6·56	8·87	222·0
26	196·42	0·62	4·95	6·77	8·38	216·0
27	208·61	0·60	3·76	6·68	7·66	209·2
28	220·81	+0·57	+2·48	−6·30	6·77	201·4

Col. Cooper's Observatory,
Markree, Collooney, Ireland.